Recently, worldwide media attention has focused on the effects of mercury pollution on the environment, and the resultant health consequences in pregnant women, fetuses, and children. Mercury occurs naturally in the environment and is a recognized neurotoxin at high doses. It cannot be broken down, thus making it one of the elements of the periodic table. Mercury naturally cycles through the natural environment beginning with concentrations in the earth’s crust, emanating into the air via coal-fired power stations, industrial incinerators, or natural phenomena such as volcanoes, and returning to soil, water, or living organisms.

Humans are exposed to mercury via several mediums including dietary intake (eg, fish consumption), dental amalgams, household agents (eg, mercury thermometers), and occupational exposure (eg, mercury in mining, dental, and pulmonary laboratories). Mercury is an effective preservative and has been used in cosmetic products, vaccines, pesticides, and fungicides.

One incident of widespread mercury poisoning occurred in Iraq in 1956 when the population had high dietary intake of seed grains contaminated with mercury-containing fungicides. This exposure resulted in an epidemic of neurological diseases and fatalities. Another notable outbreak occurred in Minimata Bay, Japan in 1956 when mercury-laden pollutants from paper mills contaminated waters containing the local populations’ fish supply. Severe neurological disease, birth defects, and many fatalities ensued. Hunter-Russell syndrome is the diagnostic label applied to the posthumous effects of methylmercury inhalation and poisoning and includes neuronal destruction and cerebral atrophy with cortical loss. Brain damage precipitating mental retardation and developmental disturbances, hypertension, and liver and metabolic insufficiencies were noted in those children of mothers exposed to contaminated fish. Children exposed in utero exhibited neurologic symptoms including chorea, ataxia, tremors, and seizures.

Aside from these large-scale incidents of mercury exposures, patients presenting with more subtle symptoms suggestive of mercury toxicity need to be recognized in the ambulatory care setting. Often the pattern of exposure to mercury—high level, acute exposure versus low level, chronic exposure—can influence the severity of presenting symptoms. The most common clinical presentations of mercury toxicity include paresthesias, ataxia, and visual effects. Differential diagnostic considerations in orthopedic practice for non-
traumatic paresthesias include carpal tunnel syndrome, cervical radiculopathy, or a peripheral neuropathy secondary to diabetes, hypothyroidism, or alcoholism.

Increasingly, health-conscious people are increasing dietary intake of fish over red meats as available ecological data suggest that fish is cardioprotective, leaner, and lower in calories. In large quantities, however, the increasing possibility of high mercury content in fish may have unanticipated consequences for the consumer. Presentation of nontraumatic clinical symptoms such as paresthesias, combined with a known abundant consumption of fish, should prompt clinical consideration and investigation of mercury toxicity in an ambulatory care setting.

This article discusses: 1) the prevalence of mercury in the natural environment; 2) pharmacology of inorganic and organic mercury; 3) relevant research findings; 4) clinical presentation and treatment of methylmercury toxicity; and 5) recommendations for safe consumption of fish.

**Distribution of Mercury in the Environment**

Mercury is an ubiquitous substance that is readily distributed in the environment from a variety natural sources and human activity, and cannot be destroyed. The three types of mercury are elemental, inorganic, and organic. Elemental and inorganic mercury are found mostly in the atmosphere, whereas different types of inorganic and organic mercury are found in water, soil, plants, and animals. Methylmercury, the organic compound that accumulates in human tissue as a result of dietary fish consumption, is the focus of this article.

Along with the aforementioned sources, mercury is also used in industry in the manufacturing of batteries, latex paint, urethane, and polyvinyl chloride. The primary source of environmental pollution is via solid waste incinerators and fossil fuel emissions, the latter of which constitutes 87% of mercury emissions in the United States. Mercury emitted from factories commonly recycles back into soil and water, leading to varying degrees of contamination. Bacteria in water methylate the mercury and convert it from its inorganic to organic form, methylmercury. In adult fish, 90%-100% of the mercury is methylmercury.

Methylmercury enters the aquatic food chain after small fish and shellfish consume this product and, in turn, transfer to larger fish via predation. Mercury bioaccumulates in the muscle tissue of larger predatory and longer-lived fish, and large fish such as pike, bass, tilefish, king mackerel, shark, large tuna, and swordfish contain the highest amounts of methylmercury. These fish can bioaccumulate methylmercury up to ten million times greater than the dissolved methylmercury concentrations in surrounding waters. Therefore, frequent consumption of these fish can result in exposure to high levels of methylmercury.

**Forms of Mercury**

To justify the rationale for ordering clinical laboratory tests, providers should be familiar with the different forms of mercury, routes of exposure, and how the body clears the substance. Elemental mercury (Hg^0) is a liquid at room temperature, and readily vaporizes. This form of mercury causes damage to the lungs when inhaled, and easily passes through the blood to the brain. Inhalation following spills of this metal on carpets is a common form of pediatric exposure resulting in poisoning. Swallowing elemental mercury may cause gastrointestinal injury. Elemental mercury can be found in mercury switches, thermostats, barometers, and thermometers, and people employed in dental and pulmonary laboratories that use mercury might be at increased risk for occupational exposure.

Clinically, exposed patients might exhibit any of a hierarchical series of symptoms beginning with an initial flu-like syndrome. During the following weeks, symptoms may progress to include involvement of the urologic, respiratory, or central nervous systems. Tertiary or advanced symptoms might include neuropsychiatric complaints including memory loss, irritability, excitability, depression, or drowsiness. This constellation of neuropsychiatric symptoms is also referred to as “erythmia.” The half-life of elemental mercury is approximately 60 days with renal excretion, and prolonged concentration in the kidneys can lead to renal failure. For detecting elemental mercury toxicity, 24-hour urine tests are most accurate, with normal levels rarely >15 μg/L.

Inorganic mercury (Hg^{2+}) that has been ingested is corrosive and commonly causes gingivitis, burning tongue, abdominal pain, nausea, vomiting, and esophageal erosions. Inorganic mercury exposure occurs primarily from ingestion of pesticides, antiseptics, and germicides. Inorganic mercury is readily absorbed by the gut with renal excretion. Neurologically, toxicity may result in dementia, tremor, and ultimate renal failure. The presence of mercury in dental amalgams continues to be a source of controversy regarding its clinical significance, with many professionals adopting the position that insufficient evidence exists to support that deleterious health effects can be traced specifically to amalgam. Epidemiological studies in Sweden found no significant effects on the renal or immune systems in adults. Ongoing concern regarding the potential adverse affect of amalgam on younger populations has prompted prospective clinical trials for further information.

Organic mercury (Hg^{2+} + CH₃) when exposed to humans leads to profound, high-dose toxicity resulting in neurological loss including paresthesias, ataxia, spasms, deafness, cognitive deterioration, and eventually coma. The ethyl- and methylmercury compounds yield the greatest damage in the fetus in utero as they cross the placental barrier and may be more neurotoxic to the fetus than to the mother. Most methylmercury exposure to
humans is from fish consumption. Consequently, the Food and Drug Administration (FDA) recommends that pregnant women and young children restrict their consumption to ≤10 g per day of fish with mercury concentrations estimated to be 0.1 and 0.15 ppm (Table).

Accurately establishing limits in methylmercury exposure via dietary intake is a less than perfect endeavor. Even if eaten in a moderate recommended quantity, a pregnant woman might readily accumulate concentrations above the recommended reference dose of 1×10⁻⁴ mg/kg-d by selecting fish with higher estimated mercury concentrations (eg, pike, swordfish, or king mackerel with an estimated 0.5 ppm). Prospective naturally reported minimal effect on neurological development in children followed prospectively over 66 months.

Mercury levels vary depending on the type and degree of underlying systemic disease (hypothyroidism, diabetes, and alcoholism) and a specific dietary history targeted at fish consumption. Kales and Goldman classified fish consumption as a product of the number of fish meals per week including “infrequent” (<1 fish meal per week), “occasional” (1-2 fish meals per week), “regular” (2-4 fish meals per week), and “high” (≥4 fish meals per week). An additional category was created for individuals at any level who reported eating swordfish regularly, as swordfish can contain 5-50 times more methylmercury than smaller fish. The clinical presentation of mercury toxicity may appear neither linear or straightforward with respect to the type and degree of symptoms. Kales and Goldman stated “a potential exposure source is a better predictor of significant mercury concentrations in biologic media than any particular constellation of health complaints.”

**ELECTRODIAGNOSTIC EVALUATIONS**

In patients with suspected mercury toxicity who present with paresthesias, electrodiagnostic evaluations can assess neurological status. Because methylmercury has a predilection for the dorsal root ganglia, abnormalities may be seen in the sensory nerves on nerve conduction studies. The most common electrodiagnostic pattern associated with mercury toxicity is impairment in sensory and motor nerves, with the myelin and axonal components of the peripheral nerve potentially involved.

To increase diagnostic clarity, it is clinically prudent to integrate any electrodiagnostic findings with a complete history of underlying systemic disease (hypothyroidism, diabetes, and alcoholism) and a specific dietary history targeted at fish consumption. Chelation therapies may be used in acute outbreaks ever possible, is recommended. Chelation therapies may be used in acute outbreaks resulting in neurological symptoms, with the caveat that this therapy can result in an increased distribution of mercury to the brain in some patients. Dialysis methods have also proven ineffective given the close affinity that the mercury compound has with the red blood cells.

**RECOMMENDATIONS FOR SAFE CONSUMPTION OF FISH**

Mercury levels vary depending on the type of fish eaten, and frequency, quantity, and duration of fish intake. As such, recommendations for safe dietary consumption of fish depend on several variables. As pregnant women, nursing women, and young children may be par-

<table>
<thead>
<tr>
<th>Parts per million (ppm)</th>
<th>Types of Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.15</td>
<td>Shellfish: Clams, crabs, scallops, shrimp, squid, octopus</td>
</tr>
<tr>
<td>0.15-1.0</td>
<td>Finfish: Anchoy, cod, Atlantic croaker, flounder, haddock, hake, herring, kingfish, some mackerel species (chub, Atlantic, jack), perch, Pollock, pompano, salmon, scup, smelt, whitefish (but not ocean whitefish), sole, whiting, turbot, sardines, and tilapia</td>
</tr>
<tr>
<td>&gt;1</td>
<td>Shellfish: Striped bass, grouper, Spanish mackerel, Northern pike, snook, and porgy</td>
</tr>
</tbody>
</table>

Table adapted from Mahaffey.
ticularly vulnerable to the effects of mercury toxicity, the FDA advises these groups to avoid intake of shark, swordfish, king mackerel, and tilefish meats. Women of childbearing age are advised to eat varieties of shellfish, canned fish, small ocean fish, or farm-raised fish to maintain a low total body burden of mercury. With a typical serving size of fish ranging from 3-6 oz, it is considered safe to eat up to 12 oz of cooked fish per week; however, a single serving of shark or swordfish, which contain 1 ppm of mercury, would exceed the daily recommendation of mercury ingestion. The 10 most commonly consumed fish species in the United States contain <0.2 ppm, whereas fish containing ≥0.5 ppm include bass, king mackerel, orange roughy, pike, and porgy.

CONCLUSION

Mercury toxicity is an infrequent differential diagnosis for patients presenting with complaints of paresthesias. Although mercury toxicity may be readily considered in light of evidence of large-scale exposure, we must be increasingly cognizant of its potential in patients identified with overabundant fish consumption. A detailed dietary history that includes quantity, frequency, and type of fish consumed is necessary to adequately consider the probability of methylmercury toxicity. If clinical suspicion is aroused, blood mercury levels should be pursued as further evidence of this phenomenon. If a 24-hour urine mercury level is elevated, clinicians should more readily consider and assess an environmental or occupational source of exposure. Electrodiagnostic studies can help rule out other causes of paresthesias such as carpal tunnel syndrome, cubital tunnel syndrome, cervical or lumbar radiculopathies, stenoses, and peripheral neuropathies. The latter can be caused by excessive exposure to mercury occupationally or by ingestion of mercury-laden fish.

To evaluate route of exposure to mercury, a blood and urine mercury test, thorough dietary evaluation of fish consumption, and electrodiagnostic testing may be necessary to establish the diagnosis and etiology that will guide appropriate medical treatment. Patient education regarding mercury exposure associated with fish consumption and healthy dietary alternatives should also be conducted.

REFERENCES

12. Skerfving S. Methylmercury exposure, mercury levels in blood and hair, and health status in Swedes consuming contaminated fish. Toxicology. 1974; 2:3-23.