Appendix A: Reference Ranges for Common Laboratory Assays of Iron Metabolism

Anthony N. Sireci and Alexander Kratz

INTRODUCTORY COMMENTS

The following is a table of reference values for laboratory tests commonly used in the workup of suspected disorders of iron metabolism. In preparing the appendix, the authors have taken into account the fact that the system of international units (SI, système international d’unités) is used in many countries and in some medical journals. However, conventional units continue to be used in many areas of the world, as well as in the lay press. Therefore, both systems are provided in the table.

A variety of factors can influence reference values. Such variables include the population studied, the duration and means of specimen transport, laboratory methods and instrumentation, and even the type of container used for the collection of the specimen. The reference or “normal” ranges given in this table may therefore not be appropriate for all laboratories, and the values should only be used as general guidelines. Whenever possible, reference values provided by the laboratory performing the testing should be utilized in the interpretation of laboratory data. Values supplied in this table reflect typical reference ranges in adults. Pediatric reference ranges may vary significantly from adult values (Kratz, Pesce, & Fink, 2008).
<table>
<thead>
<tr>
<th>Analyte</th>
<th>Specimen</th>
<th>Reference Range</th>
<th>Diagnostic Notes</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferritin</td>
<td>S</td>
<td>Female: 10–150 ng/mL Male: 29–248 ng/mL</td>
<td>Ferritin reflects total body iron stores and correlates with stainable iron in marrow. It is elevated in iron overload; however, it can also be elevated in liver disease and inflammatory states as an acute-phase reactant.</td>
<td>British Nutrition Foundation (1995)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female: 10–150 μg/L Male: 29–248 μg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepcidin</td>
<td>S</td>
<td>51.6–153.4 ng/mL</td>
<td>High levels of hepcidin, stimulated by IL-6 and IL-1, antagonize iron absorption. Levels are high in anemia of chronic disease and low in iron deficiency anemia as well as some forms of hereditary hemochromatosis.</td>
<td>Kulaksiz et al. (2004)</td>
</tr>
<tr>
<td>Iron</td>
<td>S</td>
<td>41–141 μg/dL</td>
<td>There is significant hour-to-hour and day-to-day variation in serum iron levels. Serum iron levels should therefore only be used in conjunction with other measures of iron status.</td>
<td>Kratz et al. (2008)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7–25 μmol/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean corpuscular hemoglobin (MCH)</td>
<td>WB</td>
<td>26.7–31.9 pg/cell</td>
<td>Low levels indicate prolonged iron deficiency affecting erythrocytes. Represents iron status over the past 120 days.</td>
<td>Kratz et al. (2008)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.7–31.9 pg/cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of hypochromatic red cells</td>
<td>WB</td>
<td>&lt;6%</td>
<td>A direct measure of iron deficiency, the percentage of hypochromatic red cells increases with worsening iron deficiency.</td>
<td>Tessitore et al. (2001)</td>
</tr>
<tr>
<td>Percentage of iron saturation</td>
<td>S</td>
<td>16–60%</td>
<td>An iron saturation of &lt;16% is considered inadequate for erythropoiesis. If iron saturation is &gt;100%, interference by non-transferrin iron (e.g., iron bound to ferritin) should be considered.</td>
<td>IV. NKF-K/DOQI Clinical Practice Guidelines for Anemia of Chronic Kidney Disease: Update 2000 (2001)</td>
</tr>
<tr>
<td>Test</td>
<td>Unit(s)</td>
<td>Range</td>
<td>Description</td>
<td>References</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Red cell ferritin, basic</td>
<td>WB g/cell</td>
<td>3–37.3 *10^{-17} g/cell</td>
<td>A measure of erythroid marrow iron; elevated in thalassemia and myelodysplastic syndrome; low levels in iron deficiency anemia</td>
<td>Cazzola et al. (1983)</td>
</tr>
<tr>
<td>Reticulocyte hemoglobin content (CHr)</td>
<td>WB pg/ cell</td>
<td>28–32 pg/ cell</td>
<td>A measure of the hemoglobin content of reticulocytes; allows a real-time assessment of the functional state of the erythroid marrow. Possibly, the best predictor of iron deficiency in children.</td>
<td>Fishbane, Shapiro, Dutka, Valenzuela, and Faubert (2001); Thomas and Thomas (2002)</td>
</tr>
<tr>
<td>RET-Y (Reticulocyte parameter available on certain cell counters)</td>
<td>WB arbitrary units (channel numbers)</td>
<td>1661–1820</td>
<td>A forward light scatter measure corresponding to size and content of reticulocytes. Values are lower in iron deficiency.</td>
<td>Buttarello, Temporin, Ceravolo, Farina, and Bulian (2004)</td>
</tr>
<tr>
<td>Soluble transferrin receptor (sTfR)</td>
<td>S mg/L</td>
<td>&lt;2.6</td>
<td>sTRF reflects the overall level of erythropoiesis. Elevated in Fe deficiency and with erythropoietin therapy. Not elevated in anemia of chronic disease.</td>
<td>Tessitore et al. (2001)</td>
</tr>
<tr>
<td>sTfR/ferritin index</td>
<td>S</td>
<td>&lt;1.6</td>
<td>Determined by dividing the sTfR level by the log of the serum ferritin. Increases in iron deficiency.</td>
<td>Thomas and Thomas, (2002)</td>
</tr>
<tr>
<td>Stainable iron in bone marrow</td>
<td>BM Present</td>
<td>Present</td>
<td>Gold standard for diagnosis of iron deficiency when iron stain (Prussian blue) is performed on bone marrow aspirate.</td>
<td>Jakkunen (1973); Stuart-Smith, Hughes, and Bain (2005)</td>
</tr>
<tr>
<td>Total Iron-binding capacity (TIBC) or transferrin</td>
<td>S μg/dL</td>
<td>251–406</td>
<td>Elevated in iron deficiency.</td>
<td>International Committee for Standardisation in Haematology (Iron Panel) (1978); Worwood (1997)</td>
</tr>
<tr>
<td>Transferrin saturation Zinc protoporphyrin (ZPP)</td>
<td>S μmol/mol heme</td>
<td>16–60%</td>
<td>Decreased in iron deficiency. In iron deficiency, or ferrochelatase inhibition by lead, zinc is incorporated into protoporphyrin instead of iron, leading to the generation of ZPP. The measure was originally known as free erythrocyte protoporphyrin; ZPP is elevated in iron deficiency.</td>
<td>Hastka, Lasserre, Schwarzbeck, Strauch, and Hehlmann (1992); Kulaksiz et al. (2004)</td>
</tr>
</tbody>
</table>

S: Serum; WB: Whole Blood; BM: Bone Marrow.
REFERENCES


Appendix B: *Nutritional Sources of Iron*

*Anthony N. Sireci and Alexander Kratz*

**INTRODUCTORY COMMENTS**

Common food sources vary in the quantity and type of their iron content. The following table provides information on the value of some of the most common nutrients as sources of iron (Linus Pauling Institute: Micronutrient Research for Optimum Health, 2006; McKinley Health Center University of Illinois at Urbana-Champaign, 2006; National Institutes of Health Office of Dietary Supplements, 2004).

The table is divided into non-heme (A) and heme (B) sources of iron. Heme iron is present only in foods of animal origin (meat, poultry, fish) and is absorbed more easily than non-heme iron, found in plant foods.

The iron content for each food is indicated in milligram of iron per gram of food. In the United States, federal regulations require mandatory nutrition labeling of packaged foods. This nutrition information is expressed in both common household measures appropriate to the food (e.g., one slice of bread) and in the system of international units (SI, système international d’unités). The serving size reflects the amount of food customarily consumed per eating occasion. In order to convey this information, the table lists the customary serving size for each food as determined by the US Food and Drug Administration (FDA) in both common household measures and the SI system. The iron content of one serving of each food is then given in the last column.

### Table B 1
Non-Heme Sources of Iron

<table>
<thead>
<tr>
<th>Food</th>
<th>Iron Content (mg Iron/g of Food)</th>
<th>Serving Size in Common Household Measures</th>
<th>Weight (in g) of Serving Size</th>
<th>Iron Content (in mg) of Serving Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almonds, raw</td>
<td>0.039</td>
<td>1 oz, 23 kernels</td>
<td>28.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Asparagus, canned</td>
<td>0.018</td>
<td>4 spears</td>
<td>72</td>
<td>1.3</td>
</tr>
<tr>
<td>Beans, kidney, mature seeds, cooked, boiled</td>
<td>0.029</td>
<td>1 cup</td>
<td>177</td>
<td>5.2</td>
</tr>
<tr>
<td>Beans, lima</td>
<td>0.018</td>
<td>1 cup</td>
<td>241</td>
<td>4.4</td>
</tr>
<tr>
<td>Beans, lentil, boiled</td>
<td>0.033</td>
<td>1 cup</td>
<td>198</td>
<td>6.6</td>
</tr>
<tr>
<td>Beans, navy</td>
<td>0.024</td>
<td>1 cup</td>
<td>182</td>
<td>4.3</td>
</tr>
<tr>
<td>Beans, soy</td>
<td>0.024</td>
<td>1 cup</td>
<td>180</td>
<td>4.4</td>
</tr>
<tr>
<td>Bread, wheat or white</td>
<td>0.032</td>
<td>1 slice</td>
<td>28</td>
<td>0.9</td>
</tr>
<tr>
<td>Broccoli, florettes, raw</td>
<td>0.0083</td>
<td>1 cup</td>
<td>72</td>
<td>0.6</td>
</tr>
<tr>
<td>Bulgar, cooked</td>
<td>0.0096</td>
<td>1 cup</td>
<td>182</td>
<td>1.8</td>
</tr>
<tr>
<td>Cashew nuts</td>
<td>0.060</td>
<td>18 nuts</td>
<td>28.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Cereals, 100% fortified</td>
<td>0.60</td>
<td>⅔ cup</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Cereals, 25% fortified</td>
<td>0.15</td>
<td>⅔ cup</td>
<td>30</td>
<td>4.5</td>
</tr>
<tr>
<td>Chickpeas, cooked</td>
<td>0.029</td>
<td>1 cup</td>
<td>164</td>
<td>4.7</td>
</tr>
<tr>
<td>Chocolate, baking, unsweetened</td>
<td>0.17</td>
<td>1 square</td>
<td>28.35</td>
<td>4.8</td>
</tr>
<tr>
<td>Collard greens, boiled, no salt</td>
<td>0.012</td>
<td>1 cup</td>
<td>190</td>
<td>2.2</td>
</tr>
<tr>
<td>Cornmeal, whole grain, yellow</td>
<td>0.034</td>
<td>1 cup</td>
<td>122</td>
<td>4.2</td>
</tr>
<tr>
<td>Grits, white, with water</td>
<td>0.0062</td>
<td>1 cup</td>
<td>242</td>
<td>1.5</td>
</tr>
<tr>
<td>Lettuce, butterhead</td>
<td>0.012</td>
<td>1 head</td>
<td>163</td>
<td>2.0</td>
</tr>
<tr>
<td>Oats, regular, quick and instant, unenriched, prepared with water</td>
<td>0.0068</td>
<td>1 cup</td>
<td>2.34</td>
<td>1.6</td>
</tr>
<tr>
<td>Potato, baked</td>
<td>0.011</td>
<td>1 medium</td>
<td>173</td>
<td>1.9</td>
</tr>
<tr>
<td>Prune juice</td>
<td>0.012</td>
<td>1 cup</td>
<td>256</td>
<td>3.0</td>
</tr>
<tr>
<td>Raisins, seedless</td>
<td>0.019</td>
<td>1 cup</td>
<td>145</td>
<td>2.7</td>
</tr>
<tr>
<td>Rice, brown</td>
<td>0.0061</td>
<td>1 cup</td>
<td>164</td>
<td>1.0</td>
</tr>
<tr>
<td>Rice, white, enriched</td>
<td>0.011</td>
<td>1 cup</td>
<td>158</td>
<td>1.8</td>
</tr>
<tr>
<td>Seeds, pumpkin, roasted</td>
<td>0.148</td>
<td>1 oz</td>
<td>28.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Soy milk</td>
<td>0.011</td>
<td>1 cup</td>
<td>245</td>
<td>2.7</td>
</tr>
<tr>
<td>Spinach, frozen and boiled</td>
<td>0.019</td>
<td>1 cup</td>
<td>190</td>
<td>3.7</td>
</tr>
<tr>
<td>Tofu, raw, firm</td>
<td>0.016</td>
<td>¼ block</td>
<td>81</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Table B 2
Heme Sources of Iron

<table>
<thead>
<tr>
<th>Food</th>
<th>Iron Content (mg Iron/g of Food)</th>
<th>Serving Size in Common Household Measures</th>
<th>Weight (in g) of Serving Size</th>
<th>Iron Content (in mg) of Serving Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef, composite of trimmed retail cuts, separable lean and fat, trimmed to 1/8” fat, cooked</td>
<td>0.025</td>
<td>3.0</td>
<td>85</td>
<td>2.1</td>
</tr>
<tr>
<td>Chicken, dark meat, roast</td>
<td>0.013</td>
<td>3.4 oz</td>
<td>94</td>
<td>1.3</td>
</tr>
<tr>
<td>Chicken, light meat, roast</td>
<td>0.011</td>
<td>3.5 oz</td>
<td>100</td>
<td>1.1</td>
</tr>
<tr>
<td>Clams, canned, drained</td>
<td>0.28</td>
<td>3 oz</td>
<td>85</td>
<td>23.8</td>
</tr>
<tr>
<td>Egg, boiled</td>
<td>0.012</td>
<td>1 large egg</td>
<td>50</td>
<td>0.6</td>
</tr>
<tr>
<td>Halibut, cooked</td>
<td>0.011</td>
<td>3.0 oz</td>
<td>85</td>
<td>0.9</td>
</tr>
<tr>
<td>Liver, goose, raw</td>
<td>0.31</td>
<td>3.5</td>
<td>100</td>
<td>30.5</td>
</tr>
<tr>
<td>Liver (pork, chicken) simmered</td>
<td>0.12–0.18</td>
<td>3.5 oz</td>
<td>100</td>
<td>12.0–18.0</td>
</tr>
<tr>
<td>Oysters, fried</td>
<td>0.033</td>
<td>6 medium</td>
<td>136</td>
<td>4.5</td>
</tr>
<tr>
<td>Pork, (leg, loin, shoulder, and spareribs), separable lean and fat, cooked</td>
<td>0.011</td>
<td>3.0 oz</td>
<td>85</td>
<td>0.9</td>
</tr>
<tr>
<td>Scallops, steamed</td>
<td>0.030</td>
<td>3.5 oz</td>
<td>100</td>
<td>3.0</td>
</tr>
<tr>
<td>Shrimp, cooked (moist heat)</td>
<td>0.032</td>
<td>8 large</td>
<td>44 g</td>
<td>1.4</td>
</tr>
<tr>
<td>Tuna, bluefin, cooked</td>
<td>0.013</td>
<td>3.0 oz</td>
<td>85</td>
<td>1.1</td>
</tr>
<tr>
<td>Tuna, light, in water</td>
<td>0.015</td>
<td>1 can</td>
<td>165</td>
<td>2.5</td>
</tr>
<tr>
<td>Turkey, dark meat, roasted</td>
<td>0.023</td>
<td>3.5 oz</td>
<td>100</td>
<td>2.3</td>
</tr>
<tr>
<td>Turkey, light meat, roasted</td>
<td>0.014</td>
<td>3.5 oz</td>
<td>100</td>
<td>1.4</td>
</tr>
</tbody>
</table>

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