1 Brain Parenchymal Hematoma Evolution

Juan E. Small

INTRODUCTION

Magnetic resonance imaging (MRI) can differentiate between acute, subacute, and chronic hemorrhage because of its sensitivity and specificity to hemoglobin degradation products. Therefore the imaging interpreter is, with proper knowledge, able to estimate the age of a brain parenchymal hematoma. The blood products in a hematoma evolve through a predictable variation in hemoglobin oxygenation states and hemoglobin byproducts. This predictable pattern of hematoma evolution over time leads to a specific pattern of changing signal intensities on conventional MRI.

There are limitations to the accuracy of hematoma age interpretation. Several direct and indirect factors, including the operating field strength of the magnet, the mode of image acquisition, and a wide range of biologic factors particular to the patient, may affect the imaging evolution of a parenchymal hematoma. Despite substantial variability, it is generally accepted that five stages of parenchymal hemorrhage can be distinguished by MRI. A basic understanding of the biochemical evolution of brain parenchymal hemorrhage and magnetic properties that affect MRI signal are essential for interpretation.

TEMPORAL EVOLUTION: OVERVIEW

A well-described pathophysiologic process of evolution and resorption for parenchymal hemorrhage involves five distinct phases (Fig. 1.1).

With this knowledge, the imaging interpreter can often identify the relative age of a brain parenchymal hematoma based on the T1 and T2 characteristics of the collection. However, it is important to realize that hematoma evolution is a fluid process (without static or punctuated steps). Therefore, stages of hemorrhage commonly coexist within the same hematoma because hemoglobin degradation proceeds at variable rates in the center versus the periphery of a single hematoma cavity. By convention, the most mature form of hemoglobin present defines the stage of hematoma evolution (Fig. 1.2).

TEMPORAL EVOLUTION: IN GREATER DEPTH

Extravascular blood in a hemorrhagic collection remains as oxyhemoglobin for 2 to 3 hours. The immediate activation of the clotting cascade begins the process of clot formation. Deoxyhemoglobin begins to form at the periphery of the hematoma. Eventually, the failure of metabolic pathways preventing oxidation of heme iron results in conversion of hemoglobin to methemoglobin.

In the hyperacute stage, parenchymal hemorrhage is a liquid almost completely composed of intracellular oxygenated hemoglobin. Over the course of a few hours, a heterogeneous blood clot forms within the hematoma cavity, composed of red blood cells, platelets, and serum. In the acute phase, intracellular hemoglobin becomes deoxygenated. Vasogenic edema develops in the surrounding brain parenchyma. In the early subacute phase, deoxyhemoglobin is gradually converted to intracellular methemoglobin. Then, in the late subacute phase, lysis of red blood cells leads to the release of methemoglobin into the extracellular space. During this time, the surrounding vasogenic edema slowly begins to decrease and the clot slowly retracts. In the chronic stage, macrophages and glial cells phagocytose the hematoma, leading to intracellular ferritin and hemosiderin. Eventually, the hematoma resolves and leaves a posthemorrhagic cavity with hemosiderin-stained walls.

It is critical to realize that Fig. 1.1 represents a simplified version of events designed to aid in memory. As noted previously, hematoma evolution is a fluid process (without static or punctuated steps). Stages of hemorrhage commonly coexist within the same hematoma because hemoglobin degradation proceeds at variable rates in the center versus the periphery of a single hematoma cavity (Figs. 1.3 and 1.4).

Of note, chronic posthemorrhagic parenchymal cavities may collapse nearly completely and appear as thin, relatively linear cavities with associated chronic blood products (Fig. 1.5).

Other sources of confusion include the presence of superimposed blood products of differing ages (acute or subacute hemorrhage in an area of subacute to chronic blood) or the presence of a hemorrhagic fluid level (Fig. 1.6). The presence of a blood-fluid level is moderately sensitive and highly specific for hemorrhage resulting from an underlying coagulopathy.

A NOTE ON GRADIENT ECHO SEQUENCES

Gradient echo (GRE) sequences are extremely sensitive to the paramagnetic and superparamagnetic effects of some hemoglobin breakdown products (deoxyhemoglobin, intracellular methemoglobin, ferritin, and hemosiderin). Hyperacute hemorrhage on GRE demonstrates a hypointense rim (deoxyhemoglobin) surrounding the isointense core (oxyhemoglobin). Acute and early subacute hemorrhage demonstrates diffuse hypointensity (due to deoxyhemoglobin and intracellular methemoglobin respectively). Late subacute hemorrhage demonstrates a hypointense rim (ferritin and/or hemosiderin) surrounding the hyperintense core (extracellular methemoglobin). Large areas of chronic hemorrhage demonstrate a heterogeneous/irregular hypointense rim (due to ferritin and/or hemosiderin) surrounding a posthemorrhagic encephalomalacic cavity. GRE images are not very helpful in estimating the age of small hemorrhagic foci because these appear hypointense throughout.

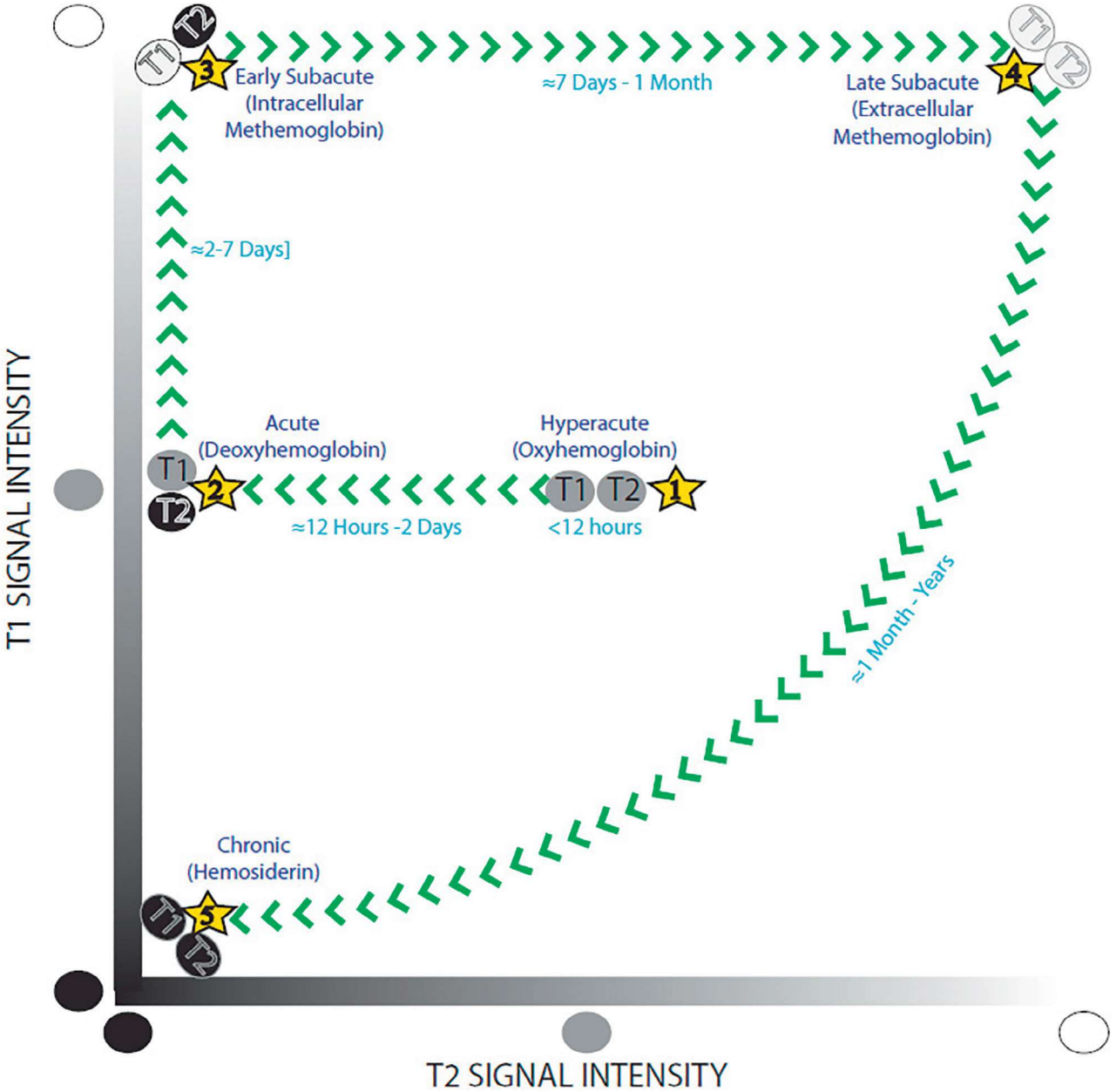

Figure 1.1. Five stages of parenchymal hematoma evolution on magnetic resonance imaging. One can easily remember the T1 and T2 characteristics of an evolving hematoma by memorizing this figure. Start from the center of the figure and move according to the direction of the arrows to remember the signal characteristics of the five distinct phases of hematoma evolution.

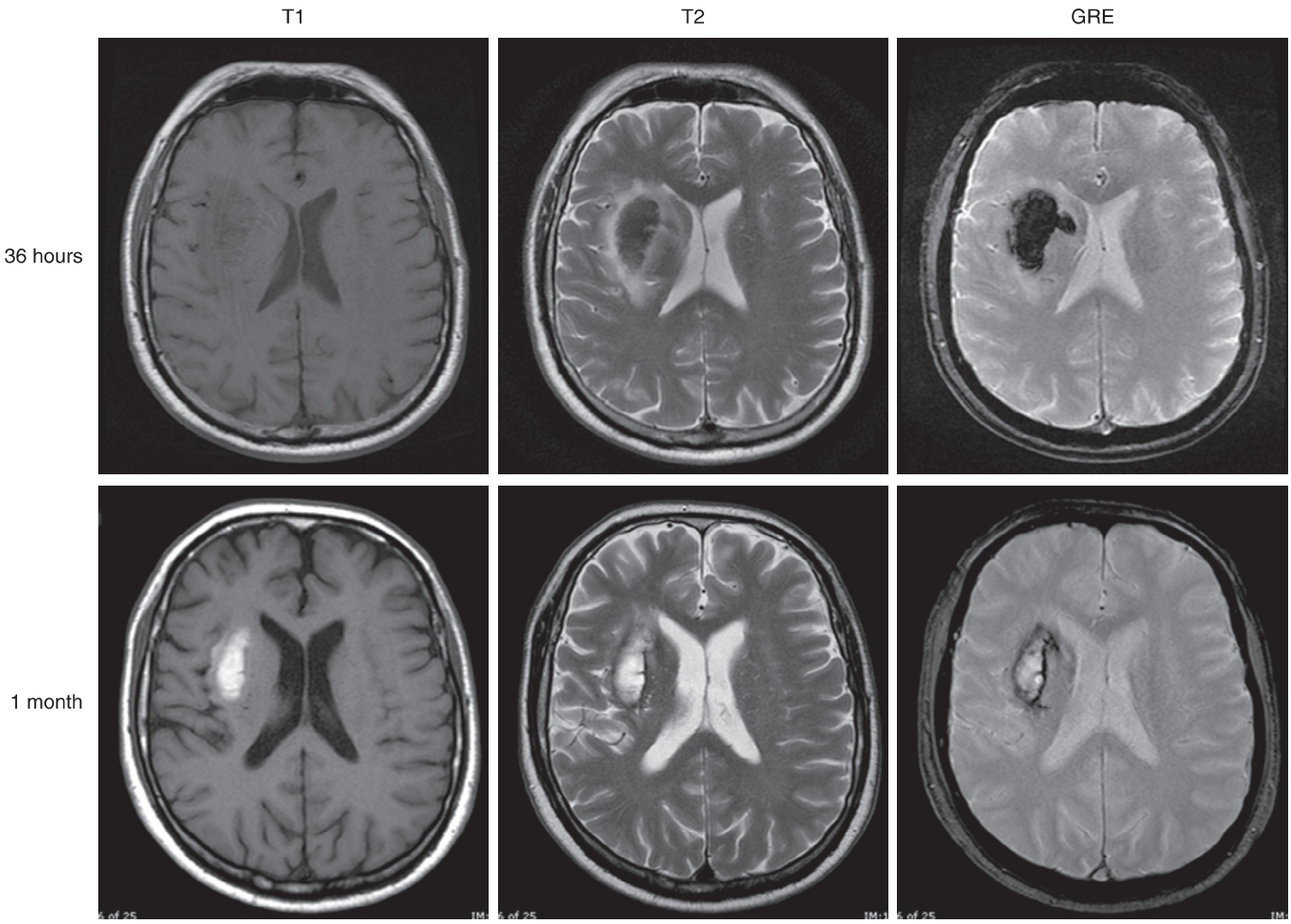

Figure 1.2. Parenchymal hemorrhage at 36 hours and at 1 month after initial presentation. At 36 hours (acute phase), T2 signal is low and T1 signal remains intermediate consistent with intracellular deoxyhemoglobin. There is diffuse hypointensity on the gradient echo *(GRE)* image due to the paramagnetic effects of deoxyhemoglobin. At 1 month (end of late subacute phase), central T1 and T2 hyperintensity is consistent with extracellular methemoglobin, while peripheral T1 and T2 low signal is consistent with hemosiderin. The rim is hypointense on the GRE image due to the superparamagnetic effects of hemosiderin. The hematoma is smaller due to retraction.

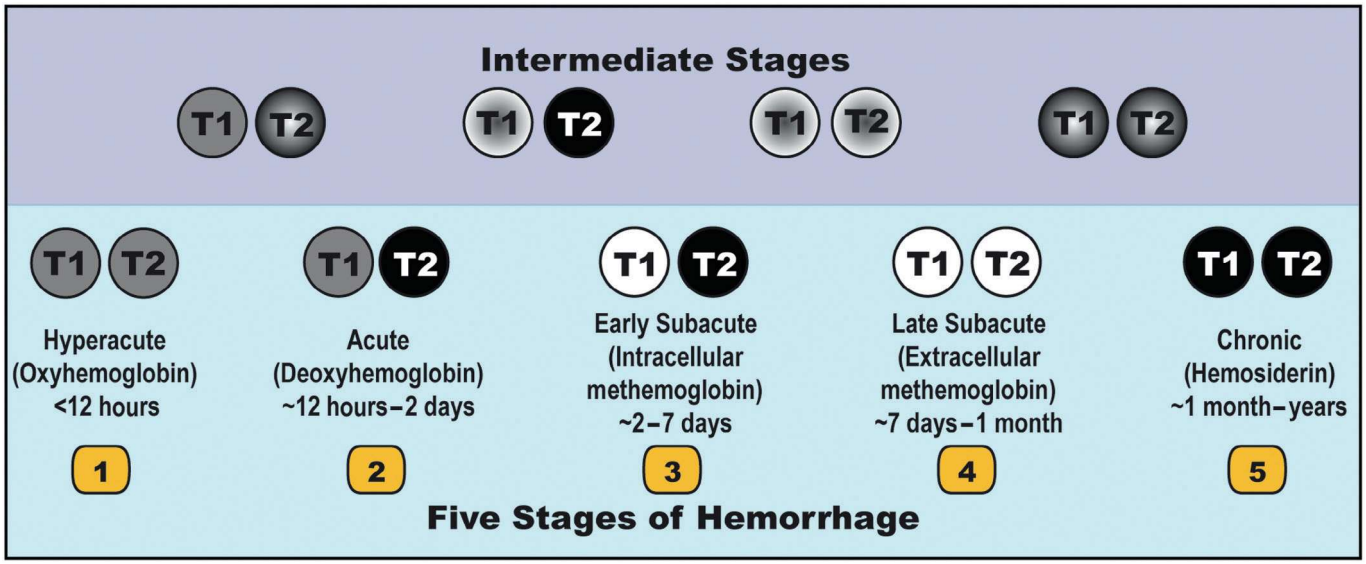

Figure 1.3. By convention, the most mature form of hemoglobin present defines the stage of hematoma evolution. The five stages of hemorrhage depicted in Fig. 1.1 are seen in the bottom row of Fig. 1.3. Each stage depicts the most mature form of hemoglobin present in the hematoma. They are not meant to imply homogeneity. The top row depicts intermediate stages of hematoma evolution between each step. In the intermediate stages, the most mature form of hemorrhage is seen at the periphery.

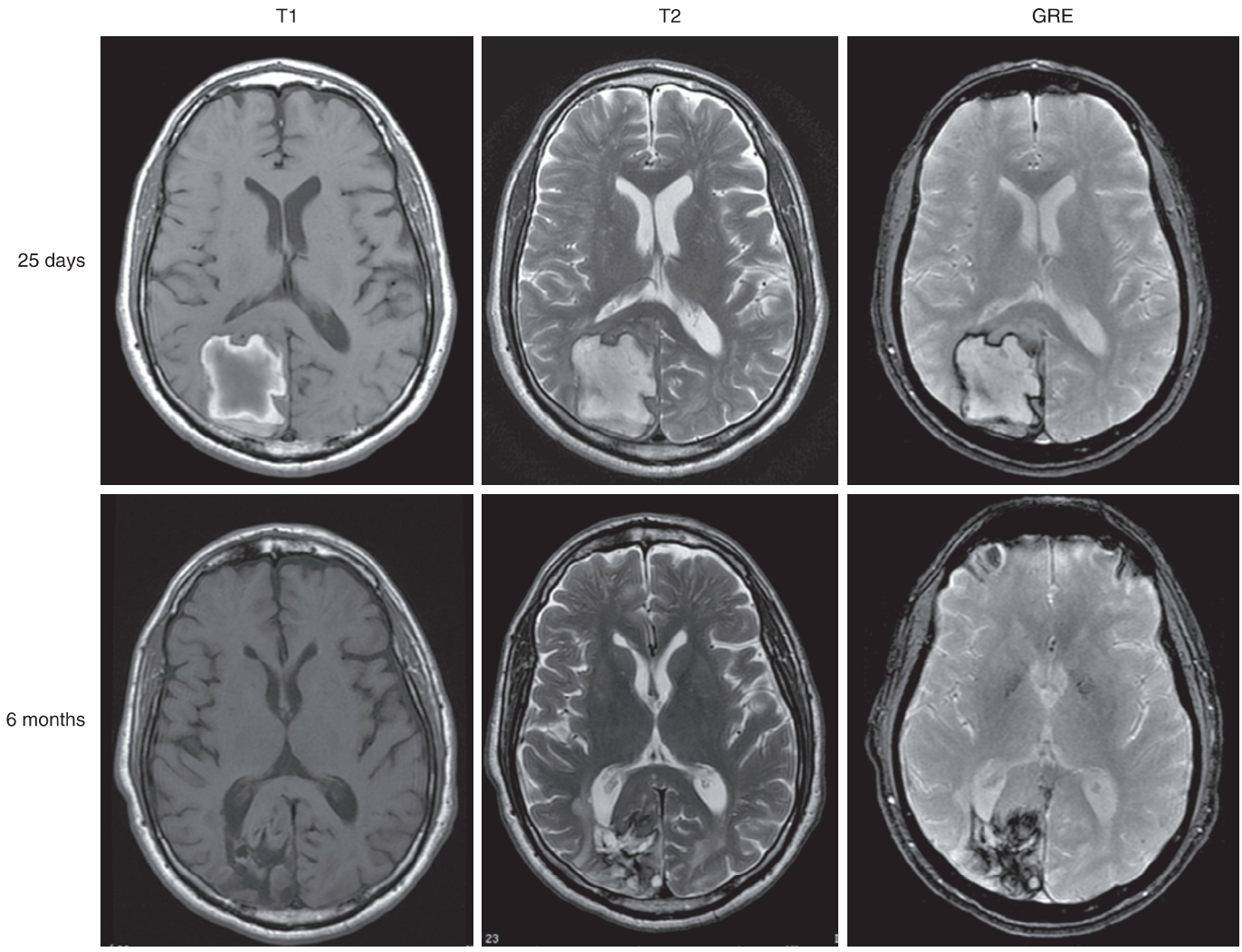

Figure 1.4. Parenchymal hemorrhage 25 days and 6 months after initial presentation. At 25 days (between early subacute to late subacute phase), there is a T1 hyperintense rim and central hypointensity consistent with methemoglobin surrounding deoxyhemoglobin. T2 signal intensity has evolved more rapidly, with near complete T2 hyperintensity, consistent with extracellular methemoglobin throughout the hematoma. At 6 months (between late subacute and chronic phases), hypointensity surrounds the encephalomalacic collapsing cavity on both T1 and T2 images consistent with hemosiderin as the most mature form of hemoglobin. The hematoma is much smaller due to retraction.

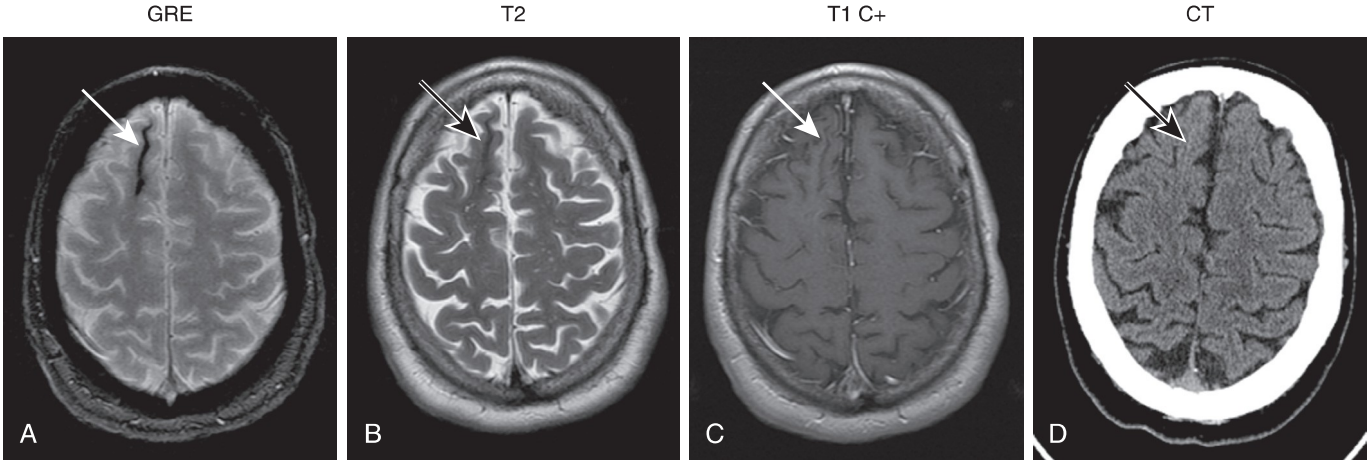

Figure 1.5. Chronic collapsed posthemorrhagic cavity. Axial magnetic resonance images (A–C) and computed tomography *(CT)* image (D) of the brain demonstrate hemosiderin within a thin collapsed T2 and T1 hypointense posthemorrhagic cavity barely visible on the CT image. *GRE*, Gradient echo.

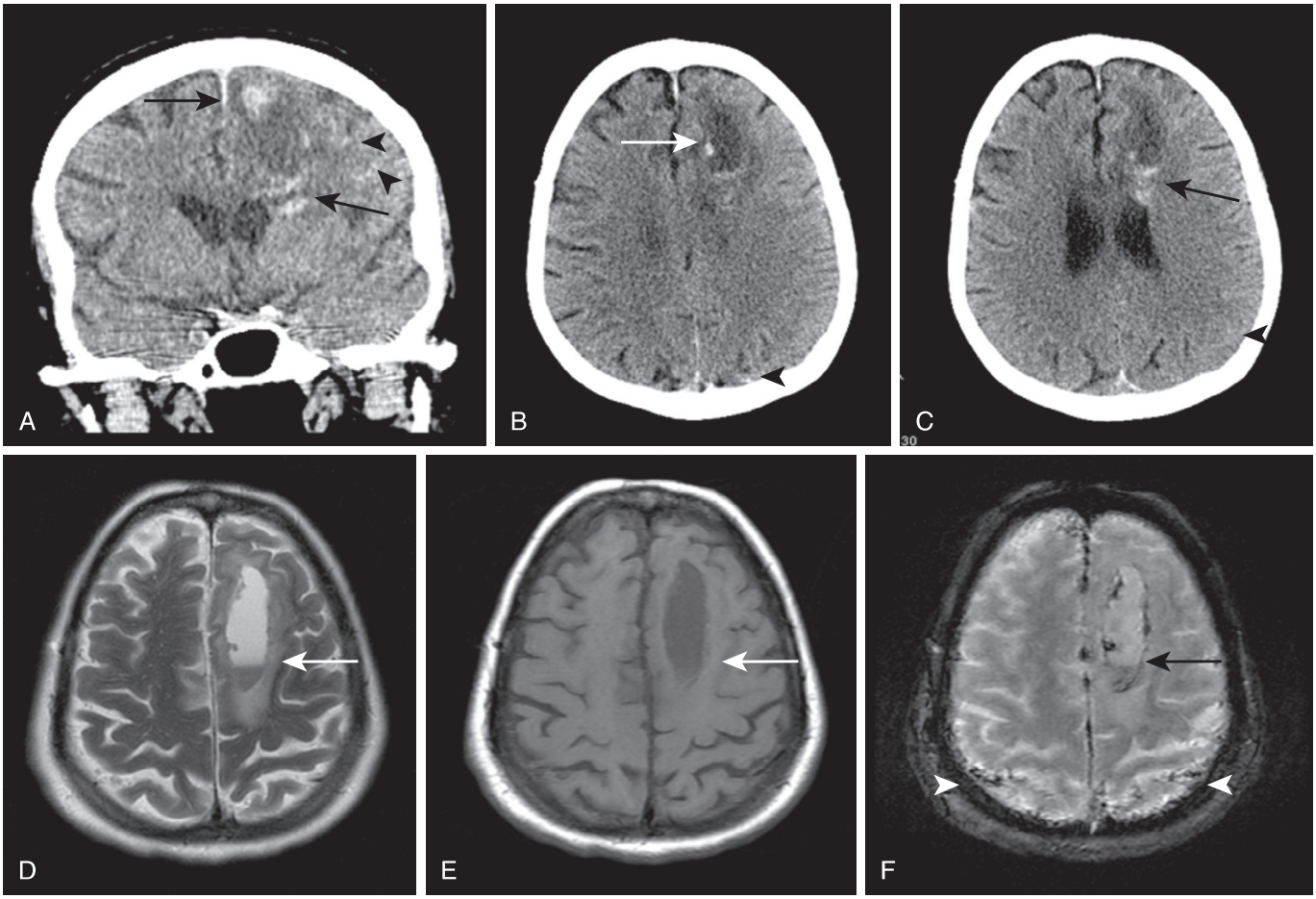

Figure 1.6. Sources of confusion—superimposed blood products of differing ages and hemorrhagic fluid levels. A patient on anticoagulation with a prior left frontal parenchymal hematoma and known subacute left frontal hemorrhagic cavity presents after an acute exacerbation. Coronal (A) and axial (B and C) computed tomography images at the time of the acute exacerbation demonstrate a hypodense left frontal hemorrhagic cavity with peripheral areas of hyperdense acute hemorrhage *(arrows)*. There are also foci of acute subarachnoid hemorrhage *(arrowheads)*. Axial T2 (D), axial T1 (E), and axial gradient echo (F) magnetic resonance imaging (MRI) images of the brain performed on the same day demonstrate a hemorrhagic fluid level within the subacute hemorrhagic cavity. Without the presence of an appropriate history, and considering the presence of multiple confounding factors, it would be difficult to predict the age of this hemorrhage based on the MRI signal characteristics alone.

SUGGESTED READING

Allkemper T, Tombach B, Schwindt W, et al. Acute and subacute intracerebral hemorrhages: comparison of MR imaging at 1.5 and 3.0 T–initial experience. *Radiology*. 2004;232(3):874–881.

Aygun N, Masaryk TJ. Diagnostic imaging for intracerebral hemorrhage. *Neurosurg Clin N Am*. 2002;13(3):313–334, vi.

Gomori JM, Grossman RI. Mechanisms responsible for the MR appearance and evolution of intracranial hemorrhage. *Radiographics*. 1988;8(3):427–440.

Kidwell CS, Wintermark M. Imaging of intracranial haemorrhage. *Lancet Neurol*. 2008;7(3):256–267.

Parizel PM, Makkat S, Van Miert E, et al. Intracranial hemorrhage: principles of CT and MRI interpretation. *Eur Radiol*. 2001;11(9):1770–1783.

Pfleger MJ, Hardee EP, Contant CF Jr, et al. Sensitivity and specificity of fluid-blood levels for coagulopathy in acute intracerebral hematomas. *AJNR Am J Neuroradiol*. 1994;15(2):217–223.