



## Software Aids for Radiologists: Part I, Useful Photoshop Skills

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**OBJECTIVE.** The purpose of this review is to describe the use of several essential techniques and tools in Adobe Photoshop image-editing software. The techniques shown expand on those previously described in the radiologic literature.

**CONCLUSION.** Radiologists, especially those with minimal experience with image-editing software, can quickly apply a few essential Photoshop tools to minimize the frustration that can result from attempting to navigate a complex user interface.

**Keywords:** Adobe Photoshop, image editing

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**A**dobe Photoshop (Adobe Systems) and other brands of image-processing software have become essential tools for radiologists, especially those involved in teaching and research. Yet many radiologists are not trained in these tools and often learn them quickly (and ineffectively) when their first projects are due. The complexity of the software can be daunting, forcing many radiologists to get by with the crude and limited basic tools they discovered or were shown in their initial attempts at image editing. Although there are excellent books that describe the full potential of Photoshop [1], radiologists need to master only a small subset of the tools available, some of which have been described in the literature [2–5].

We describe a few essential Photoshop tools that users can quickly apply. Concise, step-by-step instructions are provided to minimize the frustration that can result from attempting to navigate a complex user interface, especially for those with minimal experience. We describe the use of Photoshop CS4 on an Apple Mac running Mac OS X version 10.6.8. The commands and keystrokes may be slightly different in other versions of the operating system or of Photoshop, but most of the operations described are consistent from version to version and across platforms. The interface is slightly different on computers running the Microsoft Windows operating system, and a few of the common differences are discussed.

### Overview of Useful Photoshop Skills

Over the past decade or so, we have found the following Photoshop tools extremely useful to radiologists and believe that this review will help radiologists quickly and easily enhance their skills in manipulating images for teaching and publication. We describe the Photoshop user interface to ensure that readers can easily find and use the tools and settings described, briefly define layers and gray-scale images, and describe the useful tools.

Journals usually require that images be provided in a standard format, such as 300 pixels/inch TIFF. A group of images in a single figure usually appears more pleasing if the images are the same size along one or both of their dimensions (horizontal and vertical). In the section on resizing of images, we describe how to enlarge and reduce images and how to change the image resolution. With these skills, the user can generate, for example, several 300-pixels/inch TIFF images that are all 3 inches (7.62 cm) wide regardless of the initial size and resolution.

Two retouching tools can be used to prevent patient information from being inadvertently distributed and to clean up an image. The Clone Stamp tool is used to replace selected pixels (such as patient information) with other pixels (typically the black background of an image). This tool permanently replaces the pixels that previously contained patient information so that this information cannot be recovered. The process is more effective than covering patient information with

a black box (or similar structure) in, for example, Microsoft PowerPoint software because the black box can be deleted and the underlying patient information revealed. The Spot Healing Brush tool is used to paint over a selected area with pixels that are similar in appearance and texture to the surrounding pixels.

Although the better-known Brightness and Contrast tools can be used for quick and easy adjustment of images, changes are applied to the entire image. As a result, lightening of a dark area can result in excessive lightening of areas that previously were well visualized. We describe the powerful but less well known Shadows/Highlights tool, which can be used to lighten dark areas and darken light areas without adversely affecting the midtones.

The Line tool is used to generate lines and arrows and to control the size, shape, and color of these structures. The skills description ends with the Line Art tool, which is used to generate line-art diagrams from radiologic images.

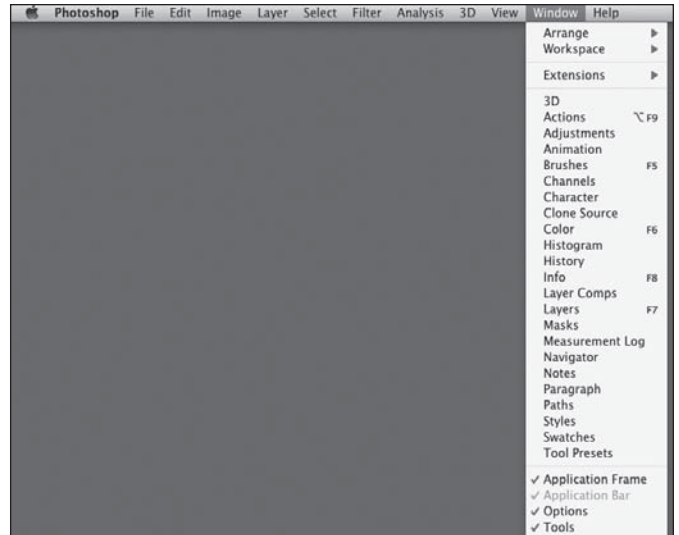
**Introduction to Photoshop**

To begin, we clarify some common terms. The terms “click” and “left-click” mean press the left mouse button once. “Right-click” means press the right mouse button once. For a single-button mouse (Mac), pressing once is equivalent to a left click, and holding down the Control key while clicking the mouse is equivalent to a right-click.

To ensure access to all the tools and options described in this review, we recommend that Mac users select, or enable, Application Frame, Options, and Tools in the Window dropdown menu, as shown in Figure 1. To do this, click on the Window dropdown menu, and a vertical list of options is displayed. If there is no checkmark to the left of Application Frame, Options, or Tools, slide the mouse down to highlight one of these lines and click once. The dropdown menu disappears, but when clicking on Window reopens the dropdown menu, a checkmark will be present on the selected line, or option. Repeat this process until checkmarks are present to the left of all three choices. (When Application Frame is checked, Application Bar is also automatically checked but is dimmed and cannot be modified). Users of Microsoft Windows select Options and Tools; Application Frame and Application Bar are not available choices.

Making the foregoing selections ensures that the Option bar and Tools panel are both visible and available for use (Fig. 2). The Tools panel usually appears on the left of the screen as a vertical panel. It is a convenient

**Fig. 1**—Window dropdown menu. Checkmarks indicate selection, or enabling, of Application Frame, Options, and Tools.



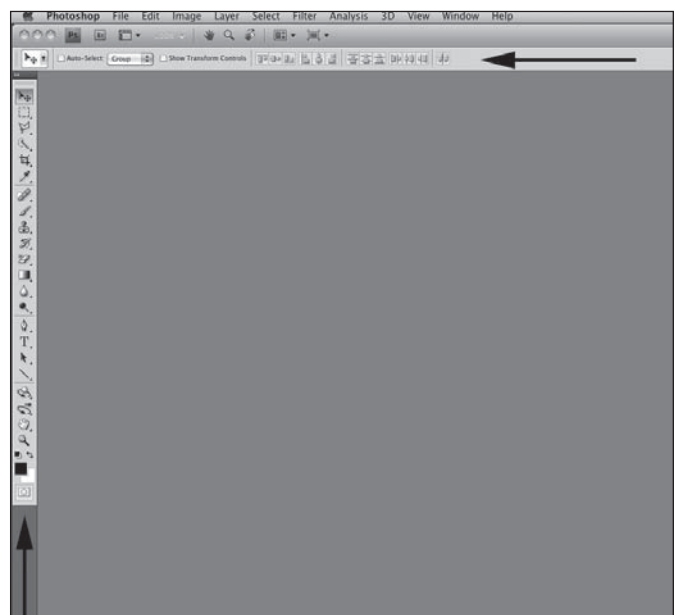
method of selecting the desired tool. Some of the tools have options that appear in the context-sensitive Options bar (meaning that the contents of the bar change depending on the tool selected). Clicking on the double arrows at the top of the Tools panel switches between displaying one tool per line and displaying two tools per line.

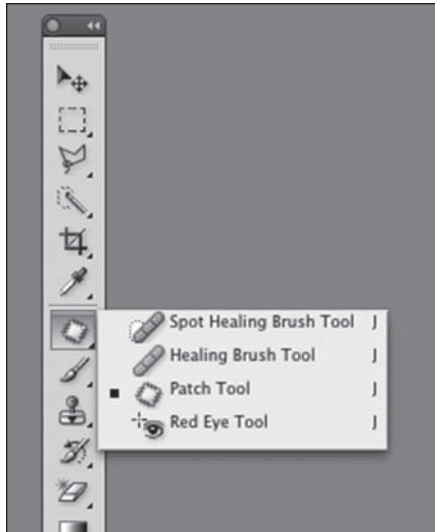
Most tools are grouped into sets of related tools. A single icon is displayed in the Tools panel for each group of tools, representing the default tool for this group or the most recently used tool in the group. A small triangle at the lower right corner of the tool icon indicates the presence of additional hidden tools in the tool group. Right-click (or

hold down the left mouse button) on any tool icon displaying the small triangle to display the currently displayed tool and all related hidden tools. In the example shown in Figure 3, the Patch tool is activated by clicking on the icon for the Patch tool in the Tools panel. To activate a tool not currently displayed in the Tools panel, such as the Spot Healing Brush tool, right-click on the icon for the Patch tool, and all the tools in this group are displayed in a small window to the right. The desired tool can be activated by sliding the cursor over the tool and clicking.

If the desired tool does not appear in the Tools panel and you do not know which group of tools it is in, simply work your way through

**Fig. 2**—Option bar (horizontal arrow) and Tools panel (vertical arrow) visible and available for use.





**Fig. 3**—Right-clicking on Patch tool in Tools panel opens window that displays related tools to right, including Spot Healing Brush, Healing Brush, and Red Eye tools.

all the displayed tools with triangles indicating hidden tools, right-clicking to see if the desired tool is listed as one of the hidden tools. This can be done fairly rapidly and allows you to find your tools until you become familiar with the grouping of tools. If the group of tools is not displayed, right-click again because two clicks are sometimes necessary, depending on your last actions.

In Photoshop, several modifier keys on the keyboard are used. These keys alter the actions of standard keys. For example, the Shift modifier key, which is identical for Mac and Windows, instructs the computer to input a capital letter (e.g., *H*) when a lowercase letter key (e.g., *h*) is pressed. The following are several keyboard modifier keys:

- Control key (labeled Ctrl or Control)
- Alt (Windows computers)
- Option (Mac computers), which may also be labeled Alt
- Command (Mac computers), which may bear the Apple icon or four leaf clover symbol in addition to or instead of the word *command*.

In almost all cases, the Command and Option keys for Mac computers are equivalent to the Ctrl and Alt keys for Windows computers.

In this review, actions for the user to take, keys to press, and input to provide are identified in quotation marks to distinguish user input from the surrounding text. Key combinations are shown with hyphens, the modifier key listed first. Thus “Command-0”

means press the Command key, hold it down while pressing the 0 (zero) key, and release both keys.

When several steps are needed to perform an action, they are listed sequentially and separated by arrows. For example, to convert an image to gray-scale, click on the Image dropdown menu at the top of the screen and slide the cursor down to highlight Mode, which brings up another menu of options, including Gray-scale, which can be selected. These steps would be designated “Image → Mode → Gray-scale.”

One of the most useful commands in Photoshop is Undo (“Command-Z”), which reverses or undoes the previous command, returning the image to its previous state.

### Layers

Photoshop has a feature called Layers, which can function as the transparent sheets of acetate used in the past with overhead projects. As with the older method, one can generate an arrow on the top layer and move it over an image on the bottom layer to control where the arrow points. Empty transparent areas of the top layer allow clear visualization of the image below. The top-layer structures can be made completely opaque, blocking the underlying portions of the lower image, or they can be made partially transparent and reveal some of the detail in the image immediately under the structure.

Layers are much more powerful than the simple acetate sheets they replace because they can function as adjustment layers that affect the appearance of the image on the layer or layers below. This feature is described later (see Shadows/Highlights).

### Initial Steps in Obtaining and Working With Gray-Scale Images

We assume in this review that users know how to export images from their PACS. It is best to export images as TIFF files because these are full-resolution images and have maximum flexibility. Although the tools we describe can also be applied to JPEG-formatted images, JPEG format is not recommended for images being edited because it usually results in so-called lossy compression and degradation of the image each time it is edited and saved. Another popular file format is GIF, which is commonly used for graphics that have a small number of colors. GIF, however, supports only 256 shades of gray and is unsuitable for processing radiologic images.

After opening an image in Photoshop, convert it to gray-scale to remove color information. Even if the image appears not to contain any color, it may have been saved as a color image, which is a larger file and less convenient to use. The steps are “Image → Mode → Gray-scale.”

### Resizing Images

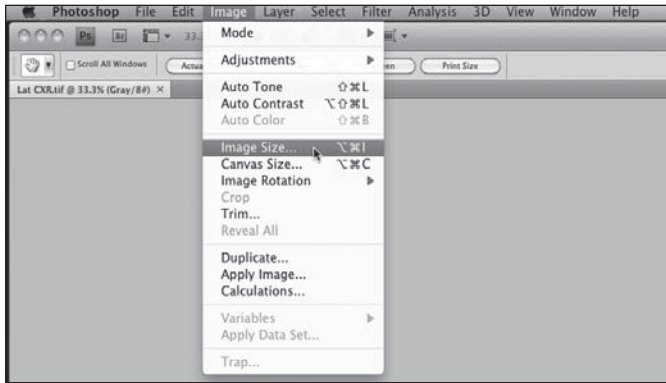
Photoshop has a convenient and powerful tool for changing the size of an image (i.e., resizing it). “Image → Image Size” (Fig. 4A) opens the Image Size window (Fig. 4B). We recommend leaving the following options checked:

- Scale Styles
- Constrain Proportions
- Resample Image

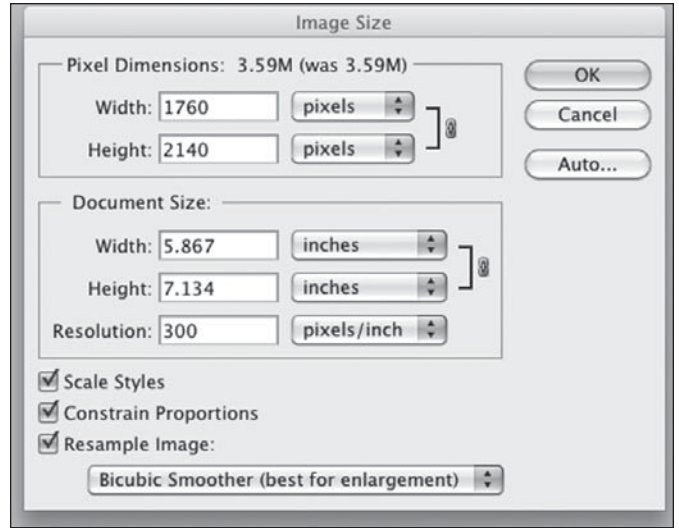
Scale Styles rescales objects such as arrows and lines you may have added, so they are changed by the same percentage as the associated image, maintaining their relative appearance, size, and location with respect to that image. Constrain Proportions ensures that the dimensions (width relative to height) of the image are not independently modified when the image is resized. Resample Image allows Photoshop to resample the image according to the selected algorithm to produce an image of the size specified by the user.

The dropdown menu at the bottom of the Image Size window (Fig. 4C) is used to specify how the image should be resampled when it is resized. Photoshop conveniently helps identify the sampling method to use by specifying the best method for enlarging (Bicubic Smoother) or reducing (Bicubic Sharper) image size. We suggest that you follow these recommendations.

When all of the foregoing parameters have been selected, the image resolution can be modified, if needed. A common resolution for printed images is 300 pixels/inch and is used in this example. Resizing is accomplished by specification of a new width or height for the image. To produce a 3-inch-wide (7.6 cm) printed image at 300 pixels/inch (also sometimes incorrectly referred to as dots per inch [dpi]), specify a width of 900 pixels (3 inches × 300 pixels/inch) in the Pixel Dimensions box. Photoshop then resamples the image using the method selected and produces a new image that is 900 pixels wide with a height proportional to the original image. Alternatively, the width can simply be set to 3 inches in the Document Size box, and Photoshop generates a 900-pixel-wide image using the previously specified resolution of 300 pixels/inch.



A



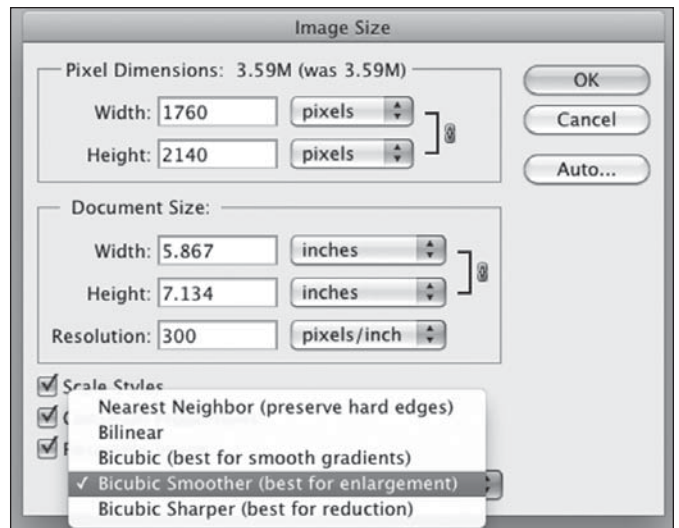
B

Fig. 4—Adjustment of image size.

A, Image Size tool accessed from Image dropdown menu.

B, Entry of desired size and in Image Size window. Options such as Scale Styles can be selected or deselected.

C, Dropdown menu for selection of algorithm for resizing image.



C

**Retouching Tools**

The following groups of retouching tools are available in Photoshop:

- Spot Healing Brush, Healing Brush, Patch, Red Eye
- Clone Stamp, Pattern Stamp
- Eraser, Background Eraser, Magic Eraser
- Blur, Sharpen, Smudge
- Dodge, Burn, Sponge

We describe the Clone Stamp and Spot Healing Brush tools. As with all editing tools used for publication, these tools should not be used to change the diagnostic information in an image [6]. They are useful for eliminating textual information not necessary on the image or that must be removed for HIPAA compliance, such as patient name and medical record number, and for removing overlying material that can confuse or complicate interpretation, such as partially visible tubes and lines, foreign bodies, and cassette artifacts.

**Clone Stamp Tool**

The Clone Stamp tool copies pixels from one portion of the image (referred to as the source or sample) to another portion of the image (referred to as the destination). The cloning or copying function is also sometimes referred to as painting. This tool is similar to the copy and paste feature in many word-processing programs, but it has additional power in that pasted pixels can be blended into the surrounding image at the destination. There

are two fundamental steps to cloning: selecting the source area to clone (i.e., copy) and specifying the destination area into which the source pixels should be pasted. Other variables that affect cloning are described in the following procedure.

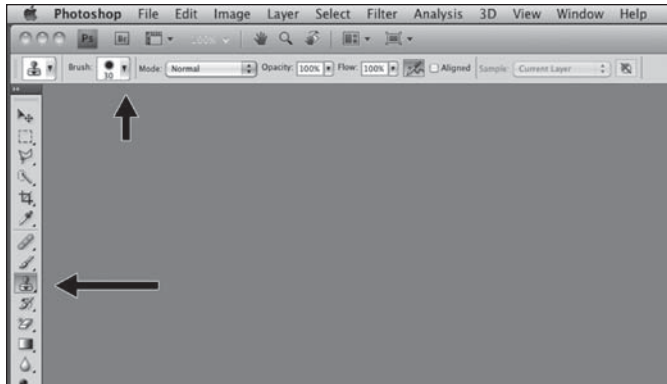
To begin using the tool, select the Clone Stamp tool from the Tool panel (Fig. 5, long arrow). Ensure that the Option bar is visible. If not, make it visible (“Window → Options”). In the Option bar, click on the downward-pointing triangle in the Brush Preset picker (Fig. 5, short arrow) to select the desired brush size (Master Diameter) and desired border sharpness (Hardness) by manually specifying these two parameters or by selecting one of the predefined brushes. We recommend beginning with the following:

- Master Diameter: 50 pixels
- Hardness: 50%

The other parameters for this tool are specified in the Option bar, as follows:

- Mode: Normal
- Opacity: 100%
- Flow: 100%
- Aligned (unchecked for now; useful when familiarity with the tool is gained)
- Sample: Current Layer

The following example (Fig. 6) shows how to copy black background over a patient’s name and medical record number while preserving the right side marker. Move the cursor over the image, where it appears as an outline of a circle, representing the brush size (Master Diameter) used for cloning the source. The brush size can be adjusted by pressing “[”

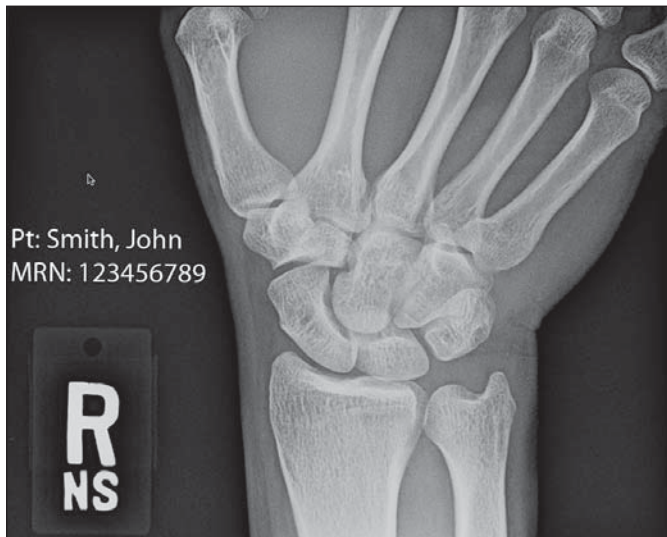


**Fig. 5**—Clone Stamp tool (*long arrow*) is selected from Tool panel. Brush size and hardness are selected by clicking on downward pointing triangle (*short arrow*) in Option bar.

and “]” (left and right bracket keys) to decrease and increase the brush size.

Select the source area from which to clone or copy pixels. Select the black background above the text to be hidden by placing the cursor in this location (Fig. 6A). Use “Option-Click” (hold down the Option key and click the mouse) to copy this area. The cursor changes to a target icon when the Option key is held down and turns into an outlined circle when the Option key is released.

Move the cursor to the destination area (in this example, the patient’s name and



**A**



**B**



**C**



**D**

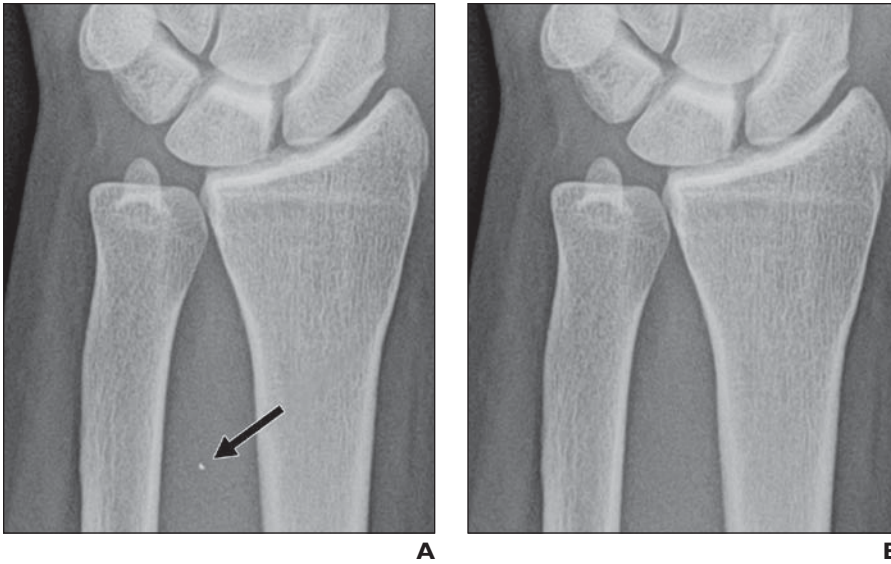
**Fig. 6**—Clone Stamp tool.

**A**, Initial image contains name and medical record number (fictional for this example), which must be removed before publication. Small arrow, or cursor, above name indicates source area being cloned, that is, black background above text.

**B**, Once appropriate size and hardness of brush are selected, clicking over medical record number copies black background being cloned over text.

**C**, Image before removal of patient information.

**D**, Image after removal of patient information.



**Fig. 7**—Foreign body removal with Spot Healing Brush tool.  
**A**, Image shows small metallic foreign body (*arrow*) overlying distal forearm.  
**B**, Final image shows results of removal of foreign body.

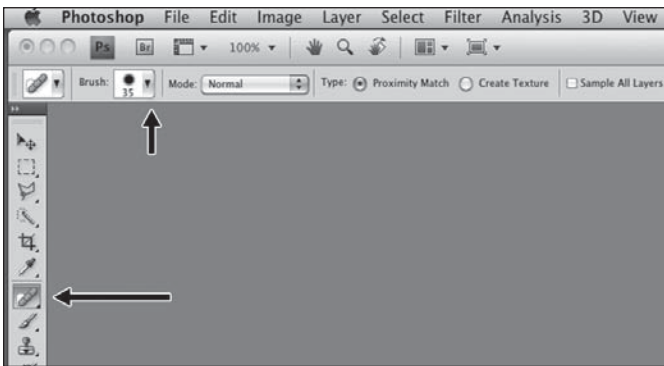
medical record number). The contents of the circle show the source pixels that will be pasted into the destination area (Fig. 6B). Note that the periphery of the circle does not completely cover the text. This effect is due

to the specified hardness of 50%, which results in blending of the pasted pixels with the original destination pixels. Click once to copy the pixels from the source to the selected destination.

To cover a larger destination area, hold down the mouse button while moving the cursor over the destination area. The source area is designated with cross hairs (a small cross or plus sign). The source pixels copied to the larger destination area are not the same pixels as the smaller area originally selected but are located at the same relative position on the image with respect to the destination area. For example, if the initial destination area is 300 pixels to the right of and 70 pixels below the source pixels, the new source pixels will always be provided by the pixels 300 pixels to the left of and 70 pixels above the destination pixels.

If the mouse button is released (with or without moving the cursor) and then held down again to continue cloning, this tool provides two options for the source pixels. It can either use the same source that was originally selected (if the Aligned option is unchecked), or it can use a new source at the same relative position as the last selection (e.g., 300 pixels to the left of and 70 pixels above the destination area, if the Aligned option is checked). In other words, each new round of cloning starts with source data from the originally selected position (if the Aligned option is not selected) or from the same relative position (if the Aligned option is selected).

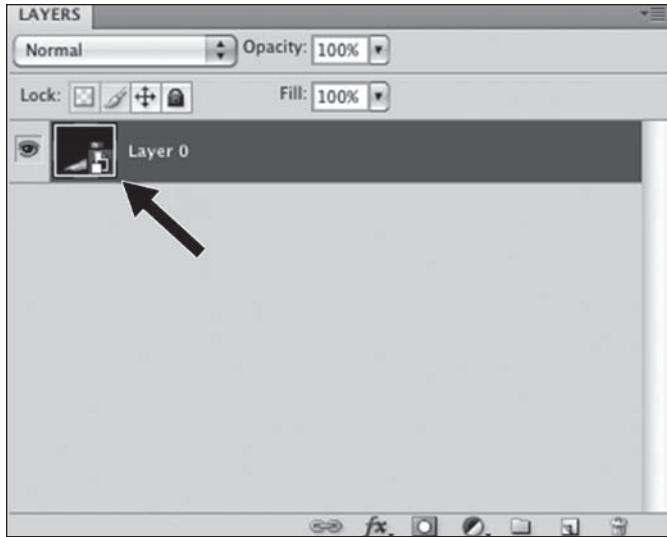
Figure 6C shows the initial image with the patient information to be removed. Figure 6D shows the final image with the patient infor-



**Fig. 8**—Spot Healing Brush tool (*long arrow*) is selected from Tool panel. Brush Picker window is opened by clicking on downward pointing triangle (*short arrow*) in Option bar.



**Fig. 9**—Shadows/Highlights.  
**A**, Original image does not show *Weight Bearing* label, and portions of foot are too bright.  
**B**, Final image after adjustments with Shadows/Highlights tool shows *Weight Bearing* label, bony structures that were too bright (such as metatarsal heads and overlapping talus and malleoli), and soft tissues that were too dark (such as tip of great toe).



**Fig. 10**—Smart Objects. Icon of overlying rectangles appears over lower right corner of image thumbnail (arrow) to indicate that image has become Smart Object.

mation removed. If the source area extends beyond the margins of the image, there is no image to clone or copy, and nothing is changed in the destination area.

**Spot Healing Brush Tool**

The Spot Healing Brush tool also replaces the specified pixels of an image. However, rather than copying them from a source specified by the user (as with the Clone Stamp tool), the Spot Healing Brush automatically samples around the specified area and replaces the selected pixels with pixels similar to their neighbors so that the area blends in with the surrounding image. This tool can be useful for replacing cassette artifacts and unrelated overlying material (foreign bodies) on an image with similar surrounding pixels. If the surrounding pixels are not appropriate for replacing the selected area, the Clone Stamp tool may be more appropriate.

The following example describes use of the Spot Healing Brush to remove an overlying foreign body from a forearm radiograph (Fig. 7A). The final corrected image is shown in Figure 7B. Select the Spot Healing Brush tool from the tool panel (Fig. 8, long arrow). On the Option Bar, click on the downward pointing triangle to open the Brush Picker window (Fig. 8, short arrow). Select the desired brush size (Diameter), border sharpness (Hardness), and Spacing by specifying these three parameters or by selecting one of the predefined brushes. We recommend starting with the following parameters:

- Master Diameter: 50 pixels
- Hardness: 50%
- Spacing: 1%

- Angle: 0°
- Roundness: 100%

Then specify the other parameters for this tool in the Option bar, as follows:

- Mode: Normal
- Type: Proximity Match
- Sample All Layers: Unchecked

To make the brush size slightly larger than the area being retouched (which allows correction with a single click), type in the desired value or increase or decrease the brush size using the “[” and “]” keys. Place the cursor (circle) over the area to be retouched and click.

**Shadows and Highlights**

Shadows/Highlights is a method for improving both the light and the dark areas of an image with a nondestructive imaging technique. When an image is modified with standard editing tools such as brightness and contrast adjustments, Photoshop (and other editing software) changes each pixel in the image to reflect the adjustments. If this edited image is opened again after it has been saved, it cannot be restored to its original appearance, which is lost or destroyed. This is not a problem if the edited image is the final version, but often, additional adjustments are needed or the image needs further editing to show different findings. Nondestructive editing allows modifications without altering the original image. Photoshop stores the original image along with information specifying the changes made. Thus the original image is available for new edits.

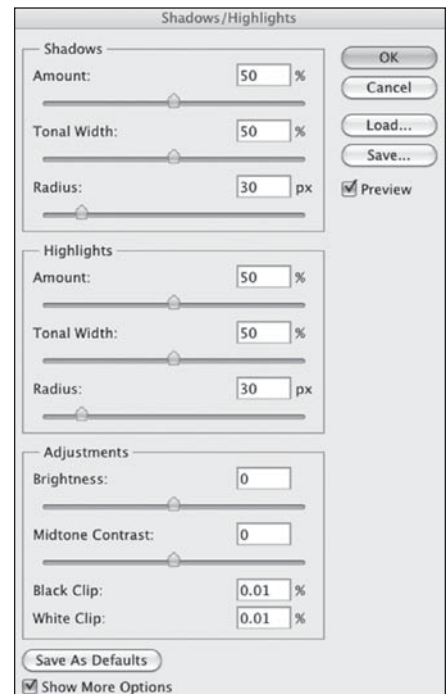
The overall brightness of an image can be adjusted with the brightness tool. However, we often need to brighten a portion of an

image while leaving the rest as is or darkening it. For example, we may want to brighten only the soft-tissue detail on a radiograph while leaving the bones unaffected or darkening them to bring back marrow detail. This frequently needed task can be accomplished with the following simple Photoshop method.

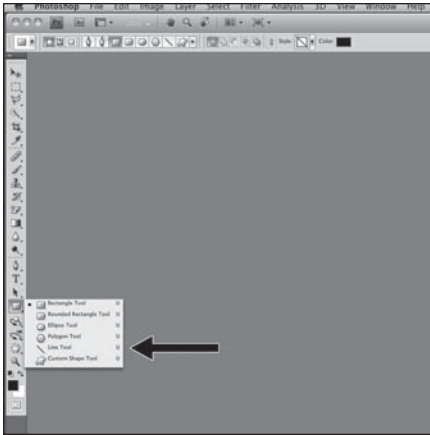
The initial image (Fig. 9A), a lateral view of the foot, shows some of these challenges. The words *Weight Bearing* near the center of the image are not visible, and subcutaneous soft tissues are not well depicted in the periphery of the leg and foot. Portions of the osseous structures, such as the overlapping bones of the metatarsal heads and the overlap of the talus with the medial and lateral malleoli, are too bright and are difficult to evaluate.

Start by ensuring that the Layers tool palette is displayed. If it is not, display it (“Windows → Layers”). In the Layers palette, right-click on the word Background and select Convert to Smart Object. A new icon appears over the right lower corner of the thumbnail of the image to indicate that it is now a smart object, and the name of the layer changes from Background to Layer 0 (Fig. 10).

Ensure that Layer 0 is selected (highlighted). If not, click on Layer 0 to select it. Activate the Shadows/Highlights tool (“Image →



**Fig. 11**—Shadows/Highlights dialog box contains sliders to control dark and bright regions of image independently and adjustments for overall brightness and mid tones.



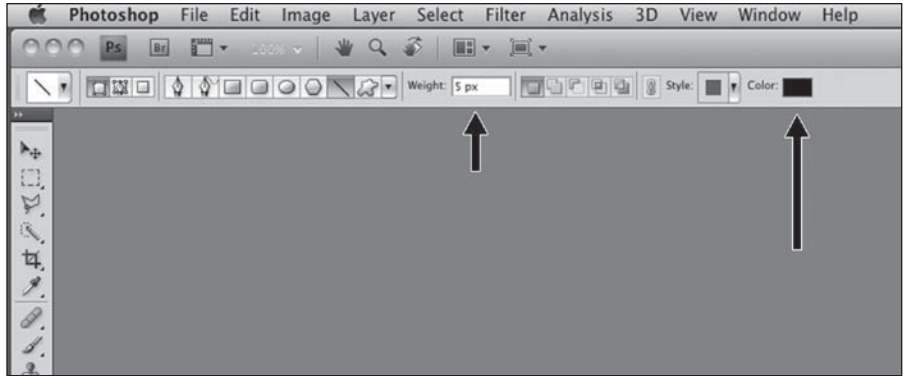
**Fig. 12**—Line Tool selection. If Line Tool is not already selected on Tool bar, right-click on related tool displayed (in this case, Rectangle Tool) to open window containing related tools. Click on Line Tool (arrow) to select it.

Adjustments → Shadows/Highlights”). In the dialog box that opens (Fig. 11), check the box next to Show More Options (at the bottom of the window), if it is not already checked.

The first three sliders affect the shadows (or darker areas of the image). Amount specifies how much to brighten the darker areas. Tonal Width specifies the width of the gray-scale area affected by this command. Larger values affect more of the midtones in addition to the shadows. If you wish to brighten only the darkest areas, select a low value. Conversely, if you wish to brighten the midtones and the darkest areas, select a large value, closer to 100%. Radius controls the size of the neighborhood around each pixel, which is evaluated to determine whether a pixel is in the shadows or highlights. A large radius tends to lighten more of the image rather than just the shadows. The next three sliders affect the Highlights (brighter areas of the image) in a manner analogous to Shadows, except that Amount specifies how much to darken the brighter areas.

In the Adjustments box, the Brightness slider affects the overall brightness of the entire image. Adjusting Midtone Contrast can help correct low-contrast or muddy-appearing midtones. We do not routinely adjust Black Clip or White Clip.

Toggling the Preview checkbox allows comparison of the original and the modified image. The resulting image (Fig. 9B) is improved, and the words *Weight Bearing* are more visible. The extent of the soft tissues is fully depicted (shown well in the anterior tibial soft tissues and the soft tissues distal to the great toe). There is improved osseous de-



**Fig. 13**—Line tool weight and color selection. Weight (width) of line is specified by typing desired size and units (in this case, 5 pixels) in Weight box (short arrow). Color is selected by clicking on Color box (long arrow).

tail of the overlapping talus and malleoli and of the overlapping metatarsal heads.

Save the final image as a TIFF file. Doing so preserves the initial image and all the editing changes made. The file can be reopened for continued editing, or the image can be restored to its original state and editing started from scratch.

The final image generally needs to be flattened for use in a publication or presentation (“Layers → Flatten”). This process eliminates the separate layers and simplifies the way the file is stored without changing the appearance of the image. The file should then be saved with a different name (e.g., lateral\_foot\_flattened) to prevent overwriting the layered file, which contains the original, unmodified image and the edits applied).

**Lines and Arrows**

The Line tool is used to draw lines and arrows. Arrows are commonly added to highlight areas of interest on a radiologic image. This section explains how to easily add lines and arrows.

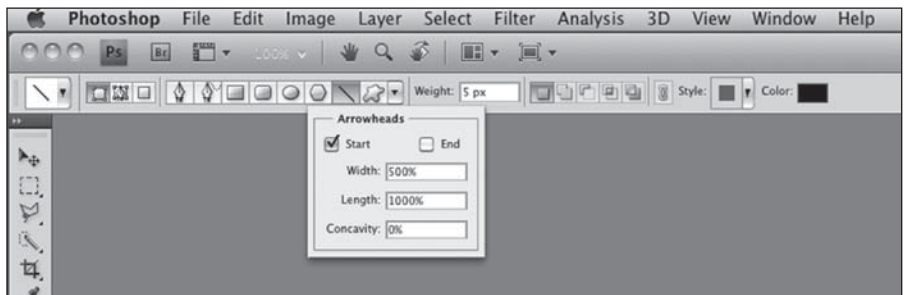
Select the line tool. If the Line Tool icon is already shown on the tool bar, click on it to select the line tool. If it is not displayed,

right-click on the related tool and select Line Tool (Fig. 12). With Line Tool selected, place the cursor where the line will begin, click and hold the mouse button, and drag the mouse to terminate the line at the desired location. The black arrow pointing to Line Tool in Figure 12 was produced with this method.

Select the width of the line before drawing the line. Specify the width by typing in its weight (width) on the Option Bar (Fig. 13, short arrow). Although the weight can be specified in inches (in) and centimeters (cm), pixels (px) are more commonly used. Start with 5 px to 20 px, and adjust up or down to produce the desired line width.

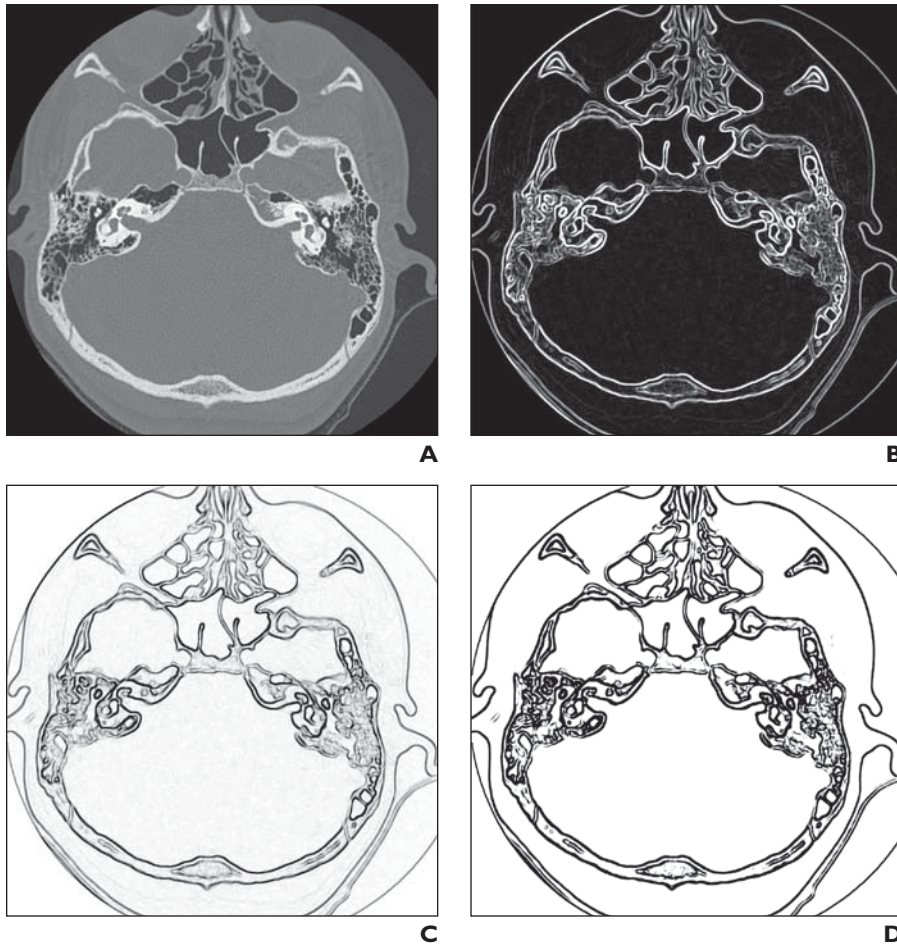
To change the color of the line, click on the colored box to the right of Color on the Option bar, and select a color for the line (Fig. 13, long arrow). For most print radiology publications, a black or white, not color, arrows are used.

To generate an arrow rather than a simple line, with Line Tool selected, click on Geometry Options (the downward pointing triangle to the left of Weight) on the Options bar. This opens the Arrowheads window (Fig. 14). Check the appropriate box to specify whether



**Fig. 14**—Arrows. Arrowhead is added to line by clicking on Geometry Options (downward pointing triangle to left of Weight). Arrowheads window is used to specify location (start, end, or both start and end of line) and size and shape of arrowhead.





**Fig. 15—Line art.**  
**A,** Initial gray-scale image of skull.  
**B,** Image after application of Glowing Edges filter shows white lines on black background.  
**C,** Image after inversion shows black lines on white background.  
**D,** Image adjusted with Levels dialog box shows fine-tuned final image.

the arrowhead should appear at the starting point of the line or at the endpoint, or check both boxes for arrowheads at both locations. The width and length of the arrowheads are with respect to the weight (width) of the line. We recommend the following values:

- Width 500%, to produce an arrowhead with maximum width 5 times as wide as the line.
- Length 1000%, to produce an arrowhead with length 10 times as long as the width of the line.
- Concavity 0, to produce simple, straight-bordered arrowheads.

The arrows are generated on separate layers and may have to be flattened in the final image, as discussed earlier in Shadows and Highlights.

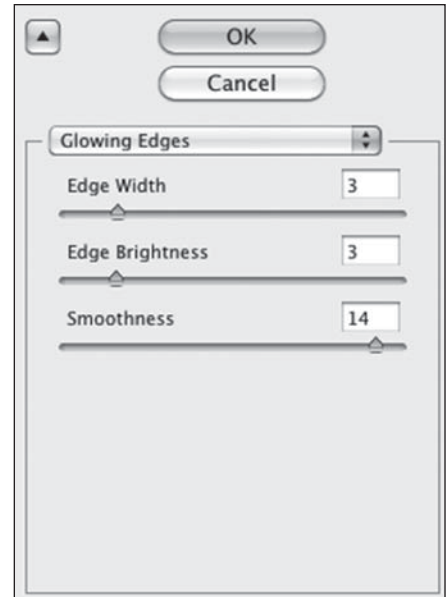
**Line Art**

A diagram outlining the main structures in an image is often useful for showing

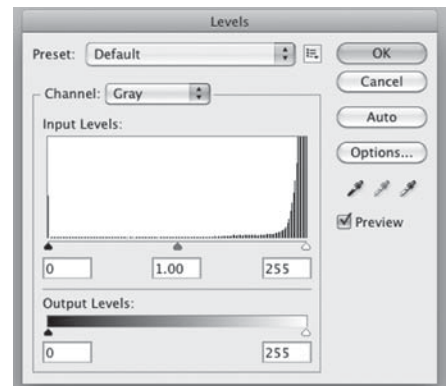
anatomic and clinical findings, particularly for teaching purposes. Use of a line-art diagram corresponding to a real radiologic image is a simplified method of showing the elements being referred to on the radiologic image.

Two techniques for generating line-art medical images have been previously reported [7]. We describe a new technique that has worked well for us and show how to create simple line-art diagrams from radiologic images. No artistic or drawing skills are required. This technique may not work with all images, especially those without well-defined edges (e.g., nuclear medicine and ultrasound studies) or with overlying structures that are interpreted as edges. However, it is a quick and simple technique and may be worth attempting for any images that may be useful as line art.

Start with a gray-scale image, such as Figure 15A. Apply the filter (“Filter → Stylize →



**Fig. 16—Glowing Edges dialog box has slider bars for setting three parameters that determine appearance of edges.**



**Fig. 17—Levels dialog box shows histogram of densities of pixels in image. Three sliders below histogram are used to modify appearance of image. Checking Preview shows changes in image appearance in real time.**

Glowing Edges”). A dialog box (Fig. 16) appears that contains three slider bars. Edge Width specifies how wide to make the edges of the image, and Edge Brightness specifies how bright to make the edges. Smoothness specifies how much detail to discard or keep in portions of the images that have less obvious edges. A high number discards much of this detail and can be useful for hiding internal structures and surrounding material. Selecting the optimal parameters can be a challenge because compromises have to be made between ensuring inclusion of all edges of interest and excluding unwanted details in

## Adobe Photoshop Skills

the image. After all parameters have been set, click the OK button to accept the changes and return to the main Photoshop window.

The image generated so far shows white lines on a black background (Fig. 15B). To convert this image to a more typical one with black lines on a white background, invert the image ("Image → Adjustments → Invert"). The image produced (Fig. 15C) may have lines that are not as well defined as desired or may show details from the original image that are distracting. Both of these issues can be addressed in the final step, in which the gray-scale levels are adjusted.

Use "Image → Adjustments → Levels" to access the Levels dialog box (Fig. 17) which contains a histogram of the densities of pixels

in the image (Input Levels). The three sliders (small triangles) along the base of the histogram control the appearance of the image. The left slider controls the darker, or blacker, areas of the image; the right slider controls the brighter, or whiter, areas of the image; and the middle slider controls the middle, or gray, areas of the image. Ensure that the Preview option is checked, so that the changes are shown on the image in real time. The final line-art image is shown in Figure 15D.

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The reader's attention is directed to part 2 accompanying this article, titled "Software Aids for Radiologists: Part 2, Essential Apps for Handheld Devices," which begins on page W714.