Measurement of Visual Strain in Radiologists[1]

Elizabeth A. Krupinski, PhD, Kevin S. Berbaum, PhD

Rationale and Objectives. The authors hypothesized that the current practice of radiology produces oculomotor fatigue that reduces diagnostic accuracy.

Materials and Methods. Testing this hypothesis required an ability to measure eyestrain. This capability was developed by measuring the visual accommodation of radiologists before and after diagnostic viewing work using an autorefractor that was capable of making multiple measurements of accommodation per second. Three radiologists and three residents focused on a simple target placed at near to far distances while accommodation was measured. The target distances varied from 20 to 183 cm from the eye. The data were collected prior to and after a day of digital diagnostic viewing.

Results. The results indicated that accommodation at near distances was significantly worse overall compared to far distances and was significantly worse after a day of digital reading at all distances.

Conclusions. Because diagnostic image interpretation is performed at near viewing distances, this inability to maintain focus on an image could affect diagnostic accuracy. As expected, younger residents had better accommodative accuracy than older radiologists.

Key Words. Visual accommodation; target distance; radiologists.

Routing imaging studies to radiologists over digital networks increases access to subspecialists and previous imaging studies. Reports are transported more rapidly, and productivity is increased. However, many digital displays still offer less contrast than film and reduced spatial resolution, information used by the visual system to regulate image focus, single vision, and the direction of gaze. Digital display could increase the strain on radiologists' eyes and reduce their performance. Our overall hypothesis was that radiology displays produce oculomotor fatigue that reduces diagnostic accuracy. The first step was to discover whether measureable eyestrain results from reading radiology displays. In this initial study, we measured the visual accommodation of radiologists before and after diagnostic viewing work.

Close work of any kind for hours on end can overwork the eyes, resulting in eyestrain (known clinically as asthenopia) (1,2). With nonmedical computer displays, just 4 hours is sufficient to produce asthenopia (3), and there is some evidence that prolonged computer use may even induce myopia in many computer users (4,5). Oculomotor fatigue caused by close work with digital displays may add to the effects of extended workdays and aging eyes (6). Although eyestrain has not been studied in radiology, we do have preliminary data showing that radiologists report increasingly severe symptoms of eyestrain, including blurred vision and difficulty focusing (see Table 1), as they read more imaging studies (7). The symptoms were assessed for film viewing only, digital viewing only, and a combination of film and digital viewing. Symptoms were worst when radiologists switched between film and digital viewing throughout the day and were less when only film examinations were read (7).

Eyestrain is caused by additional work that oculomotor systems must perform to maintain accommodation (focus), convergence (single vision), and gaze (directing the fovea). In this study, we chose to measure accommodation because the

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[1] From the Department of Radiology, University of Arizona, 1609 N Warren Building 211, Tucson, AZ 85724 (E.A.K.); and the Department of Radiology, University of Iowa, Iowa City, IA (K.S.B.). Received December 22, 2008; accepted February 4, 2009. This study was supported in part by grant R01EB004987 from the National Institute of Biomedical Imaging and Bioengineering (Bethesda, MD). **Address correspondence to:** E.A.K. e-mail: krupinski@radiology.arizona.edu

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Table 1
Correlation Between Subjective Fatigue, How Long, and How Many Cases Radiologists Read

	"How Long" Correlation		"How Many" Correlation	
Variable	*R*	*P*	*R*	*P*
Headache	0.24	.09	0.43	<.002
Eyestrain	0.43	<.002	0.48	<.001
Difficulty focusing	0.38	<.005	0.45	<.001
Blurred vision	0.34	<.02	0.42	<.002

inability to focus is often the first symptom of visual fatigue, and it has been validated by others as a reliable measure of visual fatigue (6,8–11). Double vision can occur but is less common and difficult to measure objectively. In future studies, we will measure gaze accuracy using eye-tracking equipment while observers search clinical images. Accommodative asthenopia is caused by strain of the ciliary muscles, whereas muscular asthenopia is caused by strain of the external ocular muscles. Both lead to physical symptoms: blurred or double vision, headaches, and pain in and around the eyes. Therefore, there is not a single potential cause of symptoms, and the presence of a symptom may indicate any of several different malfunctions of oculomotor control. Different work environments stress the eyes in different ways (12). For example, the inertial forces acting on the eyes of a pilot are not present in the radiology reading room. Likewise, perceptual activities, such as cine display of a computed tomographic imaging data set under viewer control, are not found in other work environments.

Our long-term goal is to determine whether increased visual fatigue that results from long hours of near computer viewing affects diagnostic accuracy. The eyes have a default accommodation distance that is called the resting point of accommodation. This is the distance at which the eyes focus when there is nothing to focus on. In total darkness, the eyes are set to focus at a particular distance, so that if the lights were turned on, an object at that distance would be in clear focus. The resting point of accommodation averages 30 inches for younger people and increases with age. Thus, near viewing is typically regarded as distances closer than the resting point of accommodation. In general, it is recommended that computer users sit 20 to 40 inches from a display, so computer use is clearly a near-viewing task (13). The goal of the present investigation was to examine visual fatigue and stress by measuring visual accommodation to find out whether there are changes in accommodation as a function of near work in radiology.

MATERIALS AND METHODS

The lens of the eye is used to alter the refractive index of light entering the eye to focus images on the retina. The lens

Figure 1. The WAM-5500 accommodation device (Grand Seiko, Hiroshima, Japan). The subject (seated in back) looks through a screen at a target (not shown). The screen at the bottom left shows the subject's eye. The joystick is used to center the eye for obtaining measurements.

is covered by an elastic capsule whose function is to mold its shape, varying its flatness and therefore its optical power. This variation in optical power is called accommodation, and it occurs as the eye focuses on a close object. We measured accommodation using a WAM-5500 Auto Refkeratometer (Grand Seiko, Hiroshima, Japan), which collects refractive measurements and pupil diameter measurements. The WAM-5500 records accommodation and hence any shifts or errors in accommodation as a function of target distance. The amount of error is a function of a number of variables, including the target distance, the visual status of the observer, and whether the observer's vision is corrected. The study was approved by the local institutional review board.

To record accommodation, the subject is seated in front of the device with the chin in a chinrest and the forehead against a headrest to maintain a stable position (see Fig 1). The device obtains an image of the eye, and the operator aligns the eye with a reticle mark using a joystick (see Fig 2). Once the eye is focused properly,