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NOVEL OBSERVATIONS AND POTENTIAL APPLICATIONS USING DIGITAL INFRARED IRIS IMAGING

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Abstract

Digital infrared (IR) iris photography using a modified digital camera system was carried out on about 300 subjects seen during routine clinical care and research at one facility. Since this image database offered opportunity to gain new insight into the potential utility of IR iris imaging, it was surveyed for unique image patterns. Then, a selection of photos was compiled that would illustrate the spectrum of this imaging experience. Potentially informative image patterns were observed in subjects with cataracts, diabetic retinopathy, Posner-Schlossman syndrome, iridociliary cysts, long anterior lens zonules, nevi, oculocutaneous albinism, pigment dispersion syndrome, pseudophakia, suspected vascular anomaly, and trauma. Image patterns were often unanticipated regardless of pre-existing information and suggest that IR iris imaging may have numerous potential clinical and research applications, some of which may still not be recognized. These observations suggest further development and study of this technology.

Introduction

Infrared (IR) imaging techniques may provide the most sensitive means to detect and record iris transillumination. Apparently, the first reports of IR iris imaging occurred during the 1970s,^{1–2} but these methods have received little attention and have not made way into routine clinical use. One possible reason for this is that older methods required specialized equipment that were not typically available to the clinician.^{3–5}

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Disclosures

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In the 1990s, one of the authors, DKR, initiated study of IR imaging in attempt to detect iris transillumination defects (ITDs) in African-Americans suspected to have pigment dispersion syndrome (PDS).⁵ Subsequent to this, in 2002, this author's group reported a simple method of detecting and recording iris transillumination using a modified digital camera system.⁶ Since then, it has been used to study PDS and other conditions affecting iris translucency. In 2003 Roberts⁷ showed that the method could detect iridociliary cysts, and since then, a number of other interesting clinical observations have been made relative to a variety of ocular conditions. Herein, we summarize these observations since this could promote further discovery.

Methods

Over a 6-year period, since the initial application of a modified digital camera system to perform IR iris photography,⁷ images from 310 consecutively photographed subjects were entered into an electronic database. All subjects were seen at a single facility, the Illinois Eye Institute, a large urban teaching facility in Chicago, Illinois, USA. Most of the subjects included Eye Institute patients seen during routine primary eye care, but students and other staff members of the facility have also been photographed. The patient population at the facility is approximately 85% African-American, and this is reflected in the composition of the database. Normal and abnormal eyes were photographed in conjunction with research protocols to experiment with the initial application of the IR method, to develop a sample of normal eye images, to evaluate images from a spectrum of disorders, to carry out a focused investigation of African-American pigment dispersion eyes, and to evaluate subjects from a clinical diagnostic standpoint who were initially examined by DKR or who were referred to him. Thus the total IR database was accumulated for a variety of reasons and is by no means fully representative of the clinic population or the spectrum of diseases that might affect iris translucency.

To give some perspective on the database composition, the median age of subjects was 52 years (range=2–94 years). There were 216 blacks, 73 whites, 9 Hispanics, 7 Asians, 2 of other descent, and 2 unknown. There were 205 females and 105 males. Included were 148 subjects with normal ocular status, 35 with classic or suspected classic PDS, 55 with the long anterior lens zonule phenotype, 11 pseudophakic subjects, 11 with angle recession or a history of eye trauma, 7 who had unexplained pigment dusting of the cornea or lens, 3 with albinism, 2 with diabetic iridopathy, 2 with Axenfeld-Rieger anomaly, 2 with Posner-Schlossman syndrome, and 2 subjects with pseudoexfoliation syndrome. Some subjects carried multiple ocular diagnoses. Several had isolated ocular hypertension or primary open-angle glaucoma. A few had retinal diagnoses only, including idiopathic choroidal folds, myopic degeneration, and retinal pigment epithelial detachment. More than 95% of the subjects photographed had comprehensive eye examinations that included gonioscopy and dilated fundus examination.

Case Reports, Observations and Example Applications

Trauma

A 33-year-old Hispanic male presented with vision loss in his left eye for six-months, which had mild dyscoria, an angle recession, and a retinal detachment involving the macula. Slit lamp exam of the iris showed a normal appearing anterior iris stroma but there was an arc-shaped IR-blocking lesion of the mid-iris from about 8:30 to 1:00 (Figure 1). The dark-brown iris did not show abnormal transillumination with traditional slit lamp biomicroscopy. The opposite eye was unremarkable. We were unable to schedule high-resolution ultrasound biomicroscopy (UBM) to determine if the lesion could be detected in an alternative way. We can only speculate that trauma may have been related to this IR-blocking iris lesion.

Iridopathy and Diabetic Retinopathy

A 52-year-old African-American male with a history of retinal photocoagulation for diabetic retinopathy had mild bilateral dyscoria, and gonioscopy showed a subtle mid-peripheral iris elevation at 9 o'clock in the left eye. Corresponding to this area was a well-delineated IR-blocking zone along the axis of pupil "peaking" (Figure 2). The IR transillumination pattern elsewhere was somewhat irregular and "patchy." The right iris also had an IR-blocking region at 6 o'clock that was dumbbell-shaped and also situated along the meridian of pupil "peaking." Re-exam of the dark-brown irides with standard slit lamp biomicroscopy did not show transillumination in either iris. UBM of the IR-blocking regions did not reveal anything unusual (Figure 2). Similar to this patient, we also saw a 41-year-old African-American male with severe nonproliferative diabetic retinopathy who had a patchy IR transmittance pattern of both irides (photos not shown). Slit lamp exam of the irides was otherwise unremarkable.

The association between diabetic retinopathy and iridopathy is well-known, and iris fluorescein angiography,⁸⁻⁹ iris indocyanine green angiography,¹⁰ and laser photometry¹¹ have been used to investigate iris microangiopathy. Iris transillumination may also provide perspective on diabetic iridopathy. In 1974 Donaldson¹² used an electronic flash lamp to photograph ITDs in diabetics and observed both patchy and stippled iris translucency. He conjectured that the stippled pattern was due to lacy vacuolation of the iris pigment epithelium, a histopathologic alteration in diabetic irides.¹³⁻¹⁴ Based on our combined observations, more may be learned about the transillumination characteristics of the diabetic iris.

Iridociliary Cysts

Slit lamp exam of a 28-year-old white female without complaint revealed a peripheral focal iris elevation at 8 o'clock in the right eye (Figure 3, Top left). Gonioscopy was normal except for minor angle obscuration in the region. The subject's brown irides did not transilluminate with the slit lamp, and eye health was otherwise unremarkable on both sides. IR iris imaging showed a small limbal zone of irregular light transmission in the iris region (Figure 3, Top right), and UBM of the right eye revealed a large iridociliary cyst in the area (Middle left).

Iridociliary cysts also altered the IR pattern in the eyes of a 50-year-old white female, whose right iris is shown in Figure 3 (Middle right). Although the cysts were pronounced on UBM, this subject did not have any iris elevation. Figure 3 also shows the IR image of a 24-year-old white female with iridociliary cysts whose iris was not elevated (Bottom left). The bottom right photo of Figure 3 shows a 65-year-old African-American female who has cortical cataracts in the pupillary zone, as well as a probable iridociliary cyst at 8 o'clock. Although we do not know what potential applications could result, we have observed the capacity of IR imaging to highlight lens opacities in many other subjects as well.

In 2003 Roberts⁷ first reported that iridociliary cysts could be visualized with IR imaging. Although usually harmless, when exaggerated, these lesions may cause angle closure glaucoma due to forward displacement of the peripheral iris.^{15–17} They may be familial¹⁶ and can be a cause of plateau iris configuration.¹⁷ Although other methods may be necessary to confirm iridociliary cysts, it occurs to us how advantageous IR imaging could be toward initial screening.

Presumed Anomalous Iris Vasculature

IR imaging of a 31-year-old white male with light-blue irides showed dark branching lines of unknown etiology in the right eye (Figure 4). The line pattern was not visible with slit lamp exam. Ocular exam was unremarkable otherwise in both eyes. So far we have not encountered any similar patterns in others, and we do not know the significance of this finding. We can only speculate that this may represent anomalous iris blood vessels. Arteriovenous iris malformations are known to occur rarely in the iris.^{18–19}

Pigment Dispersion Syndrome

The “classic” iris transillumination pattern associated with PDS consists of mid-peripheral, spoke-like defects caused by posterior iris depigmentation where there is contact with crystalline lens zonules.^{20–23} Probably because photographic methods have not been readily available to document iris translucency, the literature lacks information regarding the full spectrum of ITD patterns, ITD detection sensitivity, and ITD specificity for PDS. Unless other clinical signs clearly indicate a PDS diagnosis, inability to detect definitive PDS-related ITDs may inhibit reliable disease categorization. In addition to better detection of ITDs, particularly in dark-irides, we have been impressed by the variability of PDS-related ITD patterns. Thus, better understanding of this can be helpful in clinical care and research where classification and documentation of clinical findings is important. Along these lines, we have encountered African-American subjects for whom the detection of otherwise invisible ITDs helped establish a PDS diagnosis that would have been in doubt. We have also been surprised by the absolute inability to detect any iris transillumination, followed by the IR-assisted detection of a 360 degree ITD pattern. Figure 5 shows examples of ITD variability we have encountered. In addition to classic spoke-like defects, ITDs may be patchy and poorly-defined, which perhaps represents an opportunity to more clearly differentiate PDS of different stage or etiologies.

In addition to “classic” PDS, pigment liberation from the posterior iris may also commonly occur with long anterior lens zonules (LAZ), an anomaly related to congenitally long lens

zonules which extend abnormally close to the visual axis (Figure 5).^{24–30} Whereas classic PDS may have reverse pupillary block, posterior iris bowing, and rubbing between the mid-peripheral iris and lens zonules, LAZ subjects may have iridozonular rubbing that involves the iris more centrally, possibly at the pupillary border.^{27,30}

Posner-Schlossman Syndrome

A 50-year-old African-American male had a several year history of recurrent nongranulomatous anterior uveitis and elevated IOP in his left eye, consistent with Posner-Schlossman syndrome.³¹ Episodes resolved each time with topical therapy. Unusual, but perhaps coincidental, the patient also had longstanding bilateral PDS in both eyes, supported by Krukenberg's spindles, moderate-to-heavy trabecular meshwork pigmentation, and equatorial/posterior lens pigment. Classic, spoke-like, mid-peripheral ITDs were not present, but there were trace ITDs mainly in the 6 o'clock region of both eyes. IR imaging of the Posner-Schlossman eye showed a "speckled" ITD pattern corresponding to a pigment irregularity of the anterior iris stroma (Figure 6). The right eye did not show a similar pattern. We do not know the significance of the IR pattern here and can only speculate regarding the cause. The clinical presentation was not consistent with Fuchs' uveitis which has been reported to cause anterior iris stromal changes and IR transmittance irregularity.²

The bottom of Figure 6 illustrates the IR image of another subject with a long-term history of acute and episodic, unilateral IOP elevation associated with signs of anterior uveitis. This subject, a 73-year-old African-American male who was also presumed to have Posner-Schlossman syndrome, exhibited a pronounced sectoral region of ITDs in the affected eye. IOP had been measured as high as 70 mm Hg during exacerbations.

Pseudophakia

Figure 7 illustrates prominent sectoral light transmittance in an 83-year-old white female with posterior chamber intraocular lenses (IOLs). She had pigment dispersal signs and ocular hypertension. Laser-induced IOL alterations, an effect of capsulotomy procedures,³² were highlighted in the right eye. The outline of the other eye's IOL was also visible. Chafing of the iris pigment epithelium is a well-known complication of posterior chamber IOLs.^{33,34} Perhaps digital IR imaging could provide a convenient way to assess lens-iris interaction in post-cataract patients. With the emergence of phakic IOLs for refractive error correction and reports of related pigment dispersion,^{35–38} IR imaging might also be useful for documenting iris effects.

Figure 7 also shows the irides of a 54-year-old white male, who had piggyback^{39,40} posterior chamber IOLs implanted after cataract extraction and developed pseudophakic pigmentary glaucoma. He complained of persistent glare that was presumably due to the severe pigment excoriation from the back of his light blue iris. IR imaging showed a pronounced, 360 degree ring of iris transillumination. His glare would diminish with the use of an artificial pupil, and the IR image helped demonstrate the extent of the ITDs.

Albinism

In 1974 Donaldson¹² demonstrated use of an electronic flash lamp to photograph iris transillumination associated with albinism and other conditions. Albinism, a heritable group of conditions caused by gene mutations that result in melanin deficiency involving the skin, hair, and eyes (oculocutaneous albinism), or primarily the eye (ocular albinism), may cause iris translucency ranging from very mild to marked.⁴¹ Associated foveal hypoplasia contributes to nystagmus, strabismus, and reduced visual acuity. Whereas the detection of abnormal iris translucency is often easy, improved sensitivity coupled with convenient methods of photodocumentation may sometimes be helpful.

At present, mutations responsible for albinism states have been identified in several genes (five for oculocutaneous albinism and one for ocular albinism).⁴¹ OA1 X-linked ocular albinism is essentially limited to the eyes, and skin color is usually normal. Eye color may also be normal, and clinical diagnosis may rely on the detection of variable iris translucency and retinal pigmentary changes.^{42,43} The detection of iris translucency may be particularly important when there is decreased visual acuity but foveal hypoplasia is subclinical. The heterozygous female carrier of the OA1 X-linked ocular albinism gene is well-known to often exhibit iris translucency, and clinical identification of the carrier female can be particularly helpful during the examination of a male infant who has nystagmus and reduced vision.

Due to the clinical heterogeneity of albinism, we suspect that convenient detection and photodocumentation of iris translucency could be helpful and that exploration of the utility of IR iris examination in the description of genotype-phenotype relationships is probably warranted. Figure 7 shows images of three different albinism subjects who had IR imaging. Clear images of these subjects' irides were obtained despite poor fixation and nystagmus.

Iris Nevus

Although our experience is limited, we found that iris nevi could alter iris transmittance. Figure 9 illustrates the IR image of a subject with a benign iris nevus. The lesion is dense enough that IR light is completely blocked. We speculate that the transmittance of benign and malignant iris lesions could have variable IR patterns and that lateral extent of lesions might be delineated with IR imaging.

Additional Comment

Although IR iris imaging has been known to provide increased sensitivity in the detection of ITDs, newer technology might make this more feasible for clinical care and research. New perspective has been gained through our IR imaging work, and it is evident that there are applications, some not heretofore recognized, for which this technology could be useful.

As indicated, it is not our intent to present exhaustive reviews or definitively show the cause for the ITDs among the subjects. Rather, the intention is to share our experience with IR iris imaging to show some intriguing observations that demonstrate potential usefulness in the clinical evaluation of a wide variety of ophthalmic conditions. This experience on the whole suggests that IR iris examination may be underutilized, and important work going forward

will be to further develop a practical IR imaging method and apparatus that performs well with even the most heavily pigmented irides. Work will be required to develop software methods for image storage and analysis. These methods will then need formal validation and assessment relative to a wide range of disorders.

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Fig 1. Arc-shaped IR blocking lesion (arrows) in left eye of a 33-year-old Hispanic male who had vision loss of six-months duration, mild dyscoria, an angle recession and a retinal detachment.

Fig 2. Dyscoria and IR-blocking regions (arrows) along the axes of pupil peaking in a 52-year-old African-American male who had diabetic retinopathy and a history of panretinal photocoagulation (Top). UBM of the irides in the lesion meridians (Bottom).

Fig 3.

28-year-old white female with focal iris elevation at 8 o'clock (arrow) (Top left) had an irregular IR transmittance in the limbal region (arrows) (Top right). UBM showed the lesion to be a large iridociliary cyst (Middle left). A 50-year-old white female (Middle right) and a 24-year-old white female (Bottom left) with multiple iridociliary cysts. IR imaging highlights cortical lens opacities in a 65-year-old who has light transmission changes (arrows) that may also represent an iridociliary cyst (Bottom right).

Fig 4.
Imaging of the right eye of an otherwise normal 31-year-old male disclosed an IR-blocking pattern suggestive of branching blood vessels within the iris (arrows).

Fig 5.

IR images of subjects with PDS. A 51-year-old white male (Top left) exhibits classic spoke-like defects. 52-year-old white male (Top right) with Krukenberg's spindles, heavy trabecular pigment, and Scheie lines showed an indistinct ITD pattern. 64-year-old African-American female (2nd row left) with Krukenberg's spindles, heavy trabecular pigment, and Scheie lines showed a coalescent, 360 degree ring of mid-peripheral ITDs (arrow) not detectable without IR imaging. The highlighted club-shaped region in the pupil zone is heavy pigment on the posterior lens surface (long arrow). 67-year-old African-American

male (2rd row right) had patchy ITDs only visible with IR except for faint suggestion of the ITD at 6 o'clock. 43-year-old Hispanic male (3rd row left) with PDS signs had poorly defined, somewhat "wispy" and ring-like, ITDs that did not conform to the classic mid-peripheral spoke-like pattern. He also had a posterior subcapsular cataract (arrow) highlighted with the imaging. Long anterior lens zonules (LAZ) (arrows) in a subject (3rd row right). An ITD adjacent to the pupil (arrow) at 2 o'clock in a 58-year-old white male LAZ subject (Bottom left). A different perspective on his parapupillary iris transillumination (arrow) is gained when IR imaging is repeated after pupil dilation (Bottom right).

Fig 6.

A “speckled” IR pattern (Middle) in left eye of a 50-year-old black male with a Posner-Scholssman-like syndrome in that eye and PDS in both eyes. The right eye did not show a similar speckled pattern (Top). Both eyes showed subtle ITDs (arrows) mainly in the 6 o’clock region, presumably from PDS. 73-year-old African-American male with Posner-Schlossman syndrome and sectoral ITDs in the involved eye (Bottom).

Fig 7.

Sectoral ITDs are highlighted with IR imaging of an 83-year-old pseudophake. Laser capsulotomy-induced IOL pits appear as brighter spots (arrows) within the right pupil (Top). The outline of the IOL is visible with the IR image in the left eye (arrows) (Middle). IR imaging highlights ITDs in a 54-year-old white male who had piggyback IOL implantation and developed pigmentary glaucoma and severe glare (Bottom).

Fig 8.

Extreme iris translucency in a 19-year-old African-American male with oculocutaneous albinism (Top). In contrast, a 7-year-old white male with ocular albinism and dark-brown irides had only a few ITD patches in the right eye, one which was captured (arrow) with IR imaging (Middle). The IR imaging provided a sensitive means to evaluate the iris of the child despite eye movement and nystagmus. Clear images of diffuse iris translucency in a 49-year-old African-American male who had oculocutaneous albinism and pronounced nystagmus.

Fig 9.
Densely pigmented nevus that blocks light transmission in a 26-year-old white male.

Fig 10.

Densely pigmented nevus that blocks light transmission in a 26-year-old white man.

Standard color photograph is shown on the left and an infrared image of the nevus (arrow) is shown on the right.