Indocyanine green angiography of the anterior segment in patients undergoing strabismus surgery

Tin K J Chan, Arthur L Rosenbaum, Rajesh Rao, Steven D Schwartz, Pauline Santiago, Dennis Thayer

Abstract

Background—Anterior segment imaging using fluorescein angiography is only suitable in lightly pigmented irides as the brown pigmentation of the iris masks fluorescein transmission. Indocyanine green (ICG) angiography has excellent penetration of pigment epithelium and, therefore, has potential application in detecting perfusion changes of dark irides after strabismus surgery.

Methods—A prospective study was conducted on patients older than 15 years undergoing strabismus surgery. A fundus camera was focused on the arteriole tufts of the pupillary margin and 50 mg of ICG (concentration of 12.5 mg/ml) was given intravenously. Images were then obtained at 1 minute intervals of 5 minutes' duration.

Results—45 patients with a mean age of 54.6 years and a mean follow up period of 8.6 weeks were studied. There were 23 patients in the primary surgery group, 11 in the secondary surgery group, and 11 in the staged group. Iris ICG angiograms were successfully performed in all patients. No persistent filling deficit was detected in the primary and secondary horizontal rectus groups or in the secondary or staged vertical and combined vertical rectus groups 6–8 weeks postoperatively. 57% of both primary vertical and combined vertical and horizontal groups showed defects in the early postoperative phase. Only three cases demonstrated late perfusion defects in this series.

Conclusion—ICG can detect iris perfusion changes in dark irides after strabismus surgery. Iris reperfusion was achieved in the majority of the cases.

Materials and methods

Using ICGA, the pattern of normal iris circulation was studied. The effect of different types of rectus muscle surgery on the anterior segment circulation was evaluated. Adult patients (at least 21 years of age except one patient aged 15 years) scheduled to undergo strabismus surgery by limbal conjunctival approach were grouped as follows:

- Primary rectus muscle surgery was defined as patients with no previous strabismus surgical history or evidence of rectus muscle surgery.
- Secondary surgery was defined as surgery on a previously operated rectus muscle.
- Staged rectus muscle surgery was defined as surgery to previously unoperated rectus muscle when other rectus muscle(s) in the same eye had undergone surgery.

The Topcon TRC50 IA fundus camera was used to obtain colour AS photographs. The camera was focused on the arteriole tufts at the pupil margin. ICG at 12.5 mg/ml for a total dose of 50 mg was given via intravenous bolus at a rate of 1 ml per second. Images were obtained at approximately 1 or 2 second intervals until the iris circulation achieved maximum brightness. Images were then obtained at 1 minute intervals for 5 minutes, then at 3 minute intervals for a total duration of 30–40 minutes. Images were saved using the NEC TI-23A video camera on the Topcon Image Net H1024 digital imaging system and stored on an optical disc for analysis.
Table 1  Type of operation and presence of sectorial delay in early and late postoperative phases

<table>
<thead>
<tr>
<th>Rectus muscle</th>
<th>Number of eyes</th>
<th>Delay in filling (early)</th>
<th>Delay in filling (late)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>9</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>1 Muscle</td>
<td>4</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2 Muscles</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>9</td>
<td>6*</td>
<td>1</td>
</tr>
<tr>
<td>1 Muscle</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 Muscles</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Vertical and horizontal</td>
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<td>4†</td>
<td>None</td>
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<tr>
<td>Staged</td>
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<td></td>
<td></td>
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<tr>
<td>Horizontal</td>
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<td>None</td>
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</tr>
<tr>
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<td>1</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2 Muscles</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1 Muscle</td>
<td>2</td>
<td>NA</td>
<td>None</td>
</tr>
<tr>
<td>Vertical and horizontal</td>
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<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Secondary</td>
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<td></td>
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</tr>
<tr>
<td>Horizontal</td>
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<td>2</td>
</tr>
<tr>
<td>1 Muscle</td>
<td>5</td>
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</tr>
<tr>
<td>2 Muscles</td>
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<td>1</td>
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</tr>
<tr>
<td>Vertical</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Vertical and horizontal</td>
<td>2</td>
<td>2</td>
<td>None</td>
</tr>
</tbody>
</table>

*Three patients not available for day 1 ICG study; †one patient not available for day 1 ICG study; NA = patients not available for day 1 ICG study.

Preoperative ICG angiography was taken within 1 week before surgery. Early postoperative angiography was taken within 1 week after surgery. The mean follow up by late ICG iris angiogram was 8.6 weeks and ranged from 3 to 22 weeks after surgery. Sectorial filling delay was defined as a 10 second filling delay of over one or more clock hours. The development of adverse reactions to ICG was recorded.

Results
Preoperative strabismus diagnoses included 18 eyes (40%) of non-paralytic origin, 14 (31.1%) paralytic, nine (20%) restrictive, and four (8.9%) others. There were 24 female and 21 male patients with an age range of 15–79 years (mean age 54.6 years). Twenty-three patients had primary rectus surgery and 11 patients had secondary rectus surgery. Eleven patients had staged rectus surgery.

The ICG iris angiogram findings are displayed in Table 1. Preoperative ICG iris angiography of 23 patients (nine brown irides, 10 blue, and four green) in the primary group served as control subjects. The arm to iris circulation time ranged between 17 and 22 seconds for the ICG dye to reach the iris vasculature after injection. The filling of the dye started at variable locations peripherally from the iris root; often the nasal aspect of the iris tended to fill first and the temporal aspect followed. The superior and inferior portions filled in the intermediate phase between the nasal and temporal filling. Subsequently, filling of the iris vessels near the pupillary margin was noted. The radial vessels were joined in an incomplete circumferential fashion around the collarette, as the minor arterial circle of the iris. Filling of the whole iris usually required 5–10 seconds. Iris colour did not affect the imaging capability of ICG angiography. Figure 1A showed the filling pattern of a normal subject with brown iris.

PRIMARY RECTUS MUSCLE SURGERY (Table 1)
In the horizontal rectus surgery group, four patients underwent single rectus muscle surgery, two medial (MR), and two lateral recti (LR) respectively. Five patients had recession and resection of one horizontal rectus. In comparing the preoperative ICG angiograms with the early and late postoperative angiograms, no appreciable difference in perfusion was identified in any of the eyes.

In the vertical group, three patients had only superior rectus (SR) surgery and another four had inferior rectus (IR) surgery. Two patients had combined SR and IR surgery. Six of the nine patients were noted to have early postoperative delayed iris filling (mean delay filling time 38 seconds, range 24–56 seconds) which corresponded to the vertical recti surgery.

Figure 1B shows delayed filling of the superotemporal quadrant and is present after SR surgery. The remaining iris demonstrated a normal filling pattern. Ten weeks after SR surgery, ICGA still shows persistent delay in filling in the superior quadrant.

Figure 1C demonstrates a delayed filling in the inferior temporal quadrant after recession of the IR, and was found in two patients. No delay in filling was noted in late postoperative photographs.

Two patients demonstrated a delayed filling in the corresponding superior and inferior segments of the iris (Fig 1D) after combined SR and IR disinsertion. The iris was completely filled in late frames at 6 months.

Five patients had combined adjacent vertical and horizontal recti surgery. One patient failed to have early ICG angiogram. The remaining four patients showed delay in the vertical segmental quadrant of the operated rectus muscle in early postoperative angiograms but nine of them showed persistent perfusion defects in late angiograms.

Figure 1E shows delayed filling is present in the superotemporal quadrant after combined SR and MR surgery, but no significant delay of the filling of the medial quadrant was noted. Five months postoperatively complete reperfusion of the iris in all quadrants was seen.

SECONDARY RECTUS MUSCLE SURGERY (Table 1)
In the horizontal group, two patients had LR surgery and six patients had combined LR and MR surgery. None of these patients developed delay in filling in the early postoperative period.

In the vertical group, one patient had SR and the other one had IR surgery. Neither had early postoperative angiography, and their late angiography did not show any delay in filling. One patient (aged 58) who underwent IR and LR surgery had previous MR and LR surgery 5 months earlier. Early postoperative angiogram showed delay in filling over the corresponding inferior and temporal segments but nasal perfusion was normal (Fig 1F).

STAGED SURGERY OF THE RECTI MUSCLES (Table 1)
In the horizontal group, two patients had MR surgery years after previous rectus muscle sur-
Figure 1  (A) Normal dark brown iris ICGA of the right eye in a 49 year old man. Late frame at 46 seconds showed complete filling of the iris. (B) ICGA of the right eye in a 68 year old man. One day after primary SR surgery. Superior and temporal sectors (arrowheads) filled out of phase by 34 seconds. (C) ICGA of the left eye in a 52 year old man. One day after primary IR surgery. The nasal, superior, and temporal sectors started to fill first which was followed by a delay in filling in inferior quadrant (arrowheads) by 40.2 seconds. (D) ICGA of the right eye in a 55 year old woman. One day after primary SR and IR surgery. Superior and inferior temporal sectors (arrowheads) showed delay in perfusion by 25 seconds. (E) ICGA of the left eye in a 59 year old man. One day after primary SR and MR surgery. Persistent superior sector delay (arrowheads) by 6 minutes; no nasal sector delay in filling. (F) ICGA of the left eye (previous 5 month history of LR and MR surgery) in a 58 year old woman. One day after IR and LR surgery. Inferior and temporal sectors filled out of phase (arrowheads). Nasal sector perfusion was normal. (G) ICGA of the right eye (previous 3 year history of MR surgery) in a 81 year old man. Preoperative ICGA showed persistent temporal sector delay at late frames. Change of surgical plan and limited surgery to LR only in this eye. One day after LR surgery. Temporal sector delay (arrowheads) persisted at 38.8 seconds. (H) ICGA of the right eye (previous 18 month history of SR and IR surgery) in a 15 year old girl. One day after MR and LR surgery. Temporal sector delay (arrowheads) in filling of 27.9 seconds and nasal sector was well perfused at early frames because of the MR anterior ciliary artery preservation technique 2 months after surgery.
Indocyanine green angiography of the anterior segment in patients undergoing strabismus surgery

217

After previous combined MR and IR surgery.

Patient had a preoperative temporal filling defect.

Developed a persistent filling defect in late phase. Hayreh and Scott reported a similar fluorescein filling defect in one patient.

Based on our late ICG angiogram findings, 12 of 13 patients who showed delayed iris perfusion early after surgery had complete iris reperfusion a mean of 10.4 weeks postoperatively (range 3–22 weeks). We recommend that further strabismus surgery should be delayed for at least 12 weeks following surgery. If high risk factors are present, ICG or fluorescein iris angiogram should be considered before contemplating further rectus surgery. 

We recommend the safe interval before further rectus surgery should be at least 2 or 3 months. There were three patients with dysthyroid eye disease in our study and none of them developed sign of delay of ICG filling angiographically or any clinical sign of ASI. Olver and Scott showed that primary vertical muscle surgery was the determining factor causing sector filling delay angiographically in six patients with Graves’ ophthalmopathy.

Neither IFA nor ICG angiogram can predict which patients are likely to develop ASI postoperatively. These dyes are only able to demonstrate the degree of iris hypoperfusion preoperatively in order to allow the surgeon to change the surgical plan to try to avoid postoperative ASI.

In summary, ICG is a safe dye and is especially useful for displaying iris circulation in pigmented irides to detect perfusion changes prior to surgery. It has a further advantage of being a protein bound molecule intravascularly which allows for a precise measurement of perfusion defects.

Proprietary interest: none.


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