Utility of Large Spot Binocular Indirect Laser Delivery for Peripheral Photocoagulation Therapy in Children

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The purpose of this article is to demonstrate the utility of the large spot size (LSS) setting using a binocular laser indirect delivery system for peripheral ablation in children. One patient with bilateral retinopathy of prematurity received photocoagulation with standard spot size burns placed adjacently to LSS burns. Using a pixel analysis program called Image J on the Retcam picture, the areas of each retinal spot size were determined in units of pixels, giving a standard spot range of 805 to 1294 pixels and LSS range of 1699 to 2311 pixels. Additionally, fluence was calculated using theoretical retinal areas produced by each spot size: the standard spot setting was 462 mJ/mm² and the LSS setting was 104 mJ/mm². For eyes with retinopathy of prematurity, our study shows that LSS laser indirect delivery halves the number of spots required for treatment and reduces fluence by almost one-quarter, producing more uniform spots.

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Laser photocoagulation using an indirect laser delivery system has made it possible to treat a number of retinal diseases in children including retinopathy of prematurity (ROP), Coats disease, pars planitis, intraocular tumors, and proliferative retinopathies. In pediatric patients requiring treatment under anesthesia, the laser indirect ophthalmoscopy (LIO) delivery system is widely used for its ease and tolerability. It was first developed by Mizuno and Takaku in 1981, who attached an indirect ophthalmoscope to a laser delivery system using a fiberoptic cable. Lenses used with this method condense light from a light source to illuminate the fundus and create an aerial image that can be viewed through the binocular device. The advantages of the LIO method include increased access to the retinal periphery and increased field of view of the retina as well as the ability to treat patients in a supine position.

Two laser therapies widely used with the LIO delivery method for treatment of retinal periphery are transpupillary thermotherapy and photocoagulation therapy. The goal of transpupillary thermotherapy is to create and maintain hyperthermia with a mild rise in temperature that is not high enough for the development of coagulation. Mainster and Reichel calculated this rise to be between 4°C and 10°C using biophysical models and report hyperexpression of the heat shock protein HSP70, leading to cellular injury and apoptosis. In transpupillary thermotherapy, the diode laser (810 nm, infrared) is absorbed mainly by retinal pigment epithelium melanin as well as choroidal melanocytes to create a therapeutic effect. In contrast, photocoagulation, also referred to as laser ablation, relies on raising retinal temperatures high enough to produce coagulation of the target tissue. Wavelengths of light used can range from 500 nm to 810 nm, depending on the retinal pigments being targeted. In photocoagulation, a more significant temperature rise occurs, with retinal tissues reaching temperatures between 45°C and 65°C.

For transpupillary thermotherapy, a large spot size (LSS) setting is used, while in photocoagulation therapy, a standard
The use of LSS photocoagulation therapy using LIO is not well documented in the literature. Recently, Shah and colleagues compared the use of continuous-mode LSS diode therapy with standard spot size conventional pulsed-mode diode therapy for patients with ROP. They found that LSS photocoagulation was 40% more time efficient than conventional laser spot size. They also found that there was no difference in complication rates or outcomes when using LSS. However, this study used continuous-mode LSS therapy and was limited to patients with ROP.

One of us (J.S.P.) has used LSS laser photocoagulation of the peripheral retina since 2010. We now present the use of LSS peripheral laser photocoagulation on 7 eyes of pediatric patients with a broad spectrum of diseases including Coats disease, pars planitis, ROP, and vasculitis with peripheral neovascularization. The goal of this article is to show the magnitude of increase in retinal spot area as well as the increased uniformity achieved when using LSS for peripheral laser photocoagulation. We also report 7 eyes for which standard spot sized peripheral ablation was used to show the reduction in the number of laser spots necessary to treat when using LSS LIO as compared with the small spot size setting.

### METHODS

All patients were evaluated and treated in the Department of Ophthalmology at the Mayo Clinic, Rochester, Minnesota. Institutional review board approval for retrospective review was obtained as study number 11-006584. Visual acuity was determined using the Snellen eye chart in a formal examination with patients old enough to participate. As described in Table 1, patients 1 through 4 were treated with LSS peripheral photocoagulation. Patient 1 was treated for unilateral Coats disease; patient 2, for bilateral vasculitis with peripheral neovascularization; and patient 3, for bilateral pars planitis.

Patient 4 is a baby with bilateral prethreshold ROP for whom we used LSS in conjunction with the standard spot size to photographically document the relative size difference between the 2 spot sizes. For this patient, photograph documentation was performed by the Retcam (Clarity Medical Systems Inc) and can be seen in Figure 1.

For the 7 eyes treated from patients 1 through 4, peripheral photocoagulation was delivered using the LSS LIO (Iridex Corp) and an infrared diode laser of 810 nm (Oculight Slx; Iridex Corp) and either a 20-diopter (D) or 30-D lens (Volk Optical Inc). Laser therapy was delivered with continued observation through the lens while patients were under anesthesia and the LSS was aimed through a dilated pupil. The power and duration were adjusted to achieve white spot photocoagulation. For patients 5 through 8, similar methods and materials were used.

### Table 1. Data of Eyes Treated With Large Spot Size Laser Diode Photocoagulation

<table>
<thead>
<tr>
<th>Patient No./Sex/Age</th>
<th>Eye</th>
<th>Diagnosis</th>
<th>Examination Findings</th>
<th>Initial VA</th>
<th>Lens</th>
<th>Power/Duration</th>
<th>No. of Spots</th>
<th>Follow-up</th>
<th>Final VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/17 y</td>
<td>OS</td>
<td>Coats disease</td>
<td>Subretinal scar, hard exudates, and telangiectasia in periphery with vitreous hemorrhage</td>
<td>20/200</td>
<td>20 D</td>
<td>NR, diode</td>
<td>226</td>
<td>Return in 8 mo</td>
<td>20/400</td>
</tr>
<tr>
<td>2/M/7 y</td>
<td>OD</td>
<td>Vasculitis with peripheral neovascularization</td>
<td>2/200E</td>
<td>30 D</td>
<td>1400 mW/2000 ms</td>
<td>NR</td>
<td>1 mo</td>
<td>20/400</td>
<td></td>
</tr>
<tr>
<td>3/M/11 y</td>
<td>OD</td>
<td>Pars planitis</td>
<td>Inferior snowbank</td>
<td>20/150 + 2</td>
<td>30 D</td>
<td>900-1000 mW/9 s</td>
<td>91</td>
<td>10 mo</td>
<td>20/40 + 1</td>
</tr>
<tr>
<td>4/F/65 d</td>
<td>OD</td>
<td>ROP Adjacent spot size treatments</td>
<td>Zone 2, stage 2/3 with plus disease in both eyes</td>
<td>30 D, 1400 µm</td>
<td>600 mW/600 ms</td>
<td>410</td>
<td>11 d</td>
<td>Resolving ROP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OD</td>
<td>ROP</td>
<td>600 mW/600 ms</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OS</td>
<td>ROP</td>
<td>30 D, 350 µm</td>
<td>300 ms</td>
<td>410</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: D, diopter; NR, not reported; ROP, retinopathy of prematurity; VA, visual acuity.
were used, except standard spot size setting photocoagulation was used (Table 2). Additionally, for patient 8, alternating therapy with the 20-D and the 30-D lens was used.

When using LIO to deliver laser therapy, the 2 ways that treatment can be modified to produce the largest retinal spot size possible are by increasing the power of the condensing lens and using the larger spot size setting. A third, and less precise, way of increasing spot size is to defocus toward the patient. This can be inferred from the fact that the calculation of the true size of a spot on the fundus depends on the refraction, corneal curvatures, axial length, and magnification of the imaging system.

The Iridex LIO system can deliver 2 spot sizes with a 20-D lens: the small spot size is 350 µm and the LSS is 1400 µm. When using a 30-D lens, the retinal spot size will increase by three-thirds, or \( \times \frac{3}{2} \), given the following relationship:

\[
\text{Retinal Spot Size} = \frac{\text{Spot Size at Image Plane} \times \text{Power of Lens}}{\text{Average Refractive Power of Eye (60 D)}}
\]

Thus, assuming emmetropia and the average refraction power of the lens being 60 D, the 30-D condensing lens will produce a small spot size of 525 µm and LSS of 2100 µm.

The second way to increase the retinal spot size is by using the LSS setting, which we used in the 7 eyes of patients 1 through 4. To describe the potential efficacy of using the LSS setting, it is important to understand the differences in the area produced by each size setting. Mathematically, the theoretical area of the LSS as compared with the area of the small spot size is compared in the following equation. Assuming use of a 30-D lens with large spot diameter of 2100 µm and small spot diameter of 525 µm, the theoretical area of the spot delivered can be calculated:

\[
\begin{align*}
A_{\text{Large Spot}} &= \pi \times \left( \frac{1050}{262.57} \right)^2 = \frac{1102500}{68906.25} = 16 \\
A_{\text{Small Spot}} &= \pi \times \left( \frac{2100}{2100} \right)^2 = \pi \times 1^2 = \pi \\
\end{align*}
\]

Thus, for the Iridex LIO delivery system, one can achieve an area that is 16 times bigger when using the LSS with either a 20-D or a 30-D lens. In other words, 16 standard spots would be required to cover the area of 1 large spot. These calculations can be repeated to understand the magnitude of difference for the LIO delivery system in use.

<table>
<thead>
<tr>
<th>Patient No./Sex/Age</th>
<th>Eye</th>
<th>Diagnosis</th>
<th>Indication</th>
<th>Initial VA</th>
<th>Lens</th>
<th>Power/Duration</th>
<th>No. of Spots</th>
<th>Follow-up</th>
<th>Final VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/F/87 d</td>
<td>OD</td>
<td>ROP</td>
<td>Zone 2, stage 2/3 with early plus disease in both eyes</td>
<td>30 D</td>
<td>400-500 mW/400-500 ms</td>
<td>713</td>
<td>30 mo, 5 d</td>
<td>Light response, optic hypoplasia</td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td></td>
<td>ROP</td>
<td>Zone 1 or 2 with marked plus disease in both eyes</td>
<td>30 D</td>
<td>400-500 mW/400-500 ms</td>
<td>938</td>
<td></td>
<td>Light response</td>
<td></td>
</tr>
<tr>
<td>7/F/77 d</td>
<td>OD</td>
<td>ROP</td>
<td>Zone 1 or 2 with marked plus disease in both eyes</td>
<td>NR</td>
<td>600 mW/600 ms</td>
<td>1165</td>
<td>4 mo, 20 d</td>
<td>Resolving ROP</td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td></td>
<td>ROP</td>
<td>Marked plus disease in both eyes</td>
<td>NR</td>
<td>600-700 mW/600-700 ms</td>
<td>1135</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/M/73 d</td>
<td>OD</td>
<td>ROP</td>
<td>Zone 2, stage 3 with plus disease in both eyes</td>
<td>Alternate 20/30</td>
<td>200-400 mW/300-400 ms</td>
<td>1050</td>
<td>40 mo, 7 d</td>
<td>20/60</td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td></td>
<td>ROP</td>
<td>Marked plus disease in both eyes</td>
<td>260-540 mW/200-300 ms</td>
<td>1167</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: D, diopter; NR, not reported; ROP, retinopathy of prematurity; VA, visual acuity.

To determine the actual difference in spot size, patient 4 (baby with ROP) was treated with the standard spot size LIO and adjacent LSS LIO, both performed with a 30-D lens (Figure 1). Treatment time was adjusted to obtain similar white spot photocoagulation. Using Image J (National Institutes of Health), each standard spot area was measured in units of pixels and compared to understand the objective difference in spot variability and area. Threshold settings were set to 164 with the watershed application. The areas were reported for 6 small spots (spot labels 2, 3, 4, 6, 7, and 14) as well as for 3 large spots (spot labels 10, 13, and 16) as summarized in Figure 2 and Table 3.

In the eye of patient 4, which had adjacent spots treated with the standard spot size and LSS spot size, quantification of the respective areas was carried out using Image J. The median area for standard spot was 1020.5. The resulting range in pixel area for standard spot size was

![Image J analysis of Figure 1 can quantify the difference in pixel area of large spot size photocoagulation spots (1669-2311 pixels) and standard photocoagulation spots (805-1294 pixels), as listed in Table 3.](https://example.com/image.jpg)
is the mainstay of treatment, our data show significant
counts for the variability of adjacent spots that are “too
hot” and break the Bruch membrane next to spots that
are barely visible.

The Retcam photograph (Figure 1) also depicts in-
creased uniformity in the large spots delivered and the stan-
dard spots appear to have marked variability in size and
shape. This may be attributed, at least in part, to the re-
duced fluence achieved by using the LSS LIO. Using the
power and time settings from patient 4 who received ad-
jacent standard spot and LSS LIO, fluence was calculated
using the theoretical radii of the spot sizes when using the
30-D lens. For the standard spot size of 525 µm, calcula-
tions were made based on the diameter of 0.525 mm, mak-
ing the radius equal to 0.2625 mm. For the LSS of 2100 µm,
calculations were based on the diameter of 2.100 mm, mak-
ing the radius 1.050 mm.

\[
\text{Fluence} = \frac{\text{Power} \times \text{Time}}{\text{Area}} = \frac{\text{mJ}}{\text{mm}^2}
\]

\[
\text{Fluence}_{\text{Small Spot}} = \frac{340 \text{ mW} \times 300 \text{ ms}}{\pi (0.2625 \text{ mm})^2} = \frac{106 \text{ mJ}}{0.216 \text{ mm}^2} = 496 \text{ mJ/mm}^2
\]

\[
\text{Fluence}_{\text{Large Spot}} = \frac{600 \text{ mW} \times 600 \text{ ms}}{\pi (1.050 \text{ mm})^2} = \frac{360 \text{ mJ}}{3.46 \text{ mm}^2} = 104 \text{ mJ/mm}^2
\]

Thus, the theoretical fluence for LSS is reduced by al-
most one-quarter when compared with the fluence of stan-
dard spot size use.

We report increased uniformity in spots delivered by
LSS LIO, which may be attributed to the reduced flu-
ence delivered to the retina allowing for more con-
trolled delivery of photocoagulation therapy. We pro-
pose that the high fluence delivered to the retina by the
standard spot size setting creates a variable effect that
can lead to the marked variability observed in the shape
and uniformity of the spots delivered. Additionally, the
high fluence needed with the standard spot size ac-
counts for the variability of adjacent spots that are “too
hot” and break the Bruch membrane next to spots that
are barely visible.

For ROP, where peripheral diode photocoagulation
is the mainstay of treatment, our data show significant
reductions in the number of spots that must be deliv-
ered to treat bilateral disease. Patient 4 from the LSS treat-
ment group can be compared with patient 6 and patient
8 from the standard spot size treatment group. All 3 pa-
tients had a diagnosis of bilateral prethreshold ROP, cat-
egorized as zone 2, stage 2/3 with plus disease. For pa-
tient 4, who received treatment with the LSS setting, 820
spots were delivered to treat both eyes. This can be com-
pared with treatment received with the standard spot size
setting in patient 6, who required 1621 spots, and pa-
tient 8, who required 2217 spots to treat bilateral dis-
ease. Thus, standard spot size peripheral laser photoco-
agulation requires more time, as supported by Shah and
colleagues.19 Thus, for children requiring broad areas of
photocoagulation under anesthesia, the LSS setting can
reduce time under anesthesia and time spent delivering
treatment.

The limitations of this study are that it is retrospec-
tive with a small sample size. Additionally, a random-
ized controlled trial is needed in which time to achieve
LSS ablation is compared with time spent administering
small spot size ablation. There is a paucity of literature
on the efficacy of using LSS in peripheral laser photoco-
agulation, but the safety and long-term outcomes are as-
sumed to be equivalent to using the standard small spot
size.

Standard spot size is ideal for focal areas of treat-
ment; however, for large treatment areas, the LSS set-
ting shows promise. This article demonstrates the mag-
nitude of increase in retinal spot area achieved when
using LSS for peripheral laser ablation. Given the the-
oretical increase in retinal area achieved with LSS com-
bined with the 30-D condensing lens, we report a re-
duced number of spots required to deliver treatment, as
well as the ability to deliver spots with increased unifor-
mity and reduced fluence. We conclude that the LSS
setting is an improved technique that should be more
widely used when performing peripheral laser photoco-
agulation in pediatric patients and adults requiring LIO
photocoagulation, such as elderly or cognitively im-
paired individuals.

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