Background: Vascular malformations and cavernous hemangiomas are common in childhood. Although cavernous hemangiomas may resolve spontaneously, aggressive intervention is required when their growth could damage vital adjacent structures, such as the orbit, nose, or tongue.

Objective: To evaluate the efficacy of interstitial Nd:YAG photocoagulation as an adjunct to intralesional and systemic corticosteroids for treatment of hemangiomas and vascular malformations that had failed to respond to other therapies.

Design: Prospective, nonrandomized trial.

Setting: Two referral practices of facial plastic and reconstructive surgery in tertiary care, academic medical centers.

Patients: Ten consecutive pediatric patients with either hemangioma or vascular malformation of the head and neck.

Intervention: Laser photocoagulation with an interstitial technique. The Nd:YAG fiber was introduced into the lesion via a 14-gauge angiocatheter needle, and the laser fiber was advanced as coagulation proceeded within the tissue.

Main Outcome Measures: Decrease in the area of the target lesion, amount of energy applied, and number of treatments required to achieve reduction in size.

Results: Long-term follow-up demonstrated regression of the lesion in all 10 patients with good cosmetic results. The range of reduction in size was 20% to 98%. No reexpansion of the lesions was noted after a mean follow-up of 13 months.

Conclusions: Interstitial photocoagulation of hemangiomas and vascular malformations is an effective treatment for carefully selected patients. When properly applied, this technique can achieve reduction in the size of these lesions without compromising cosmesis.


Hemangiomas and vascular malformations can be physically disfiguring for the afflicted individuals as well as psychologically taxing for the parents of infants and children born with these lesions. Rarely, the lesions may be life threatening. Hemangiomas are the most common of all birthmarks and represent the most common benign tumor of infancy. As many as 3% to 8% of infants develop hemangiomas during their first months of life.

Historically, the nomenclature for vascular malformations has been confusing, but recent literature is more clear. Mulliken and Glowacki published a classification scheme of vascular malformations, dividing these lesions into hemangiomas and other vascular malformations. Differentiation between these 2 lesions by means of their classification is based on anatomical and structural features and biological behavior.

Vascular malformations are present at birth and affect male and female infants with an equal incidence. Displaying a normal rate of endothelial growth, the lesions increase in size as the patient grows. Vascular malformations do not regress spontaneously, but undergo darkening and thickening of the surface of the lesion over time. Histologically, vascular malformations may be divided according to their component vessels. These include capillary vascular malformations (port-wine stains), and arterial, venous, lymphatic, and combined lesions.

Hemangiomas afflict females 3 times more commonly than males. The hemangioma is not present at birth but appears and enlarges during the first weeks to months of life. After this proliferative phase, there is a quiescent period, fol-
PATIENTS AND METHODS

Ten patients were treated with interstitial Nd:YAG photocoagulation for definitive treatment of hemangiomas (n=8) or vascular malformations (n=2). Preoperative evaluation in all 10 patients included complete history and physical examination, laboratory analysis (hematocrit, platelet count, and urinalysis), and radiographic studies. In most cases, the diagnosis of hemangioma or vascular malformation was confirmed clinically and radiographically, with histological confirmation performed in only 1 case. Evaluation of a vascular lesion appropriate for intralesional Nd:YAG photocoagulation included magnetic resonance (MR) imaging to determine the depth and extent of the lesion, and to plan treatment approaches that would protect and preserve vital anatomical structures. Imaging is particularly important in facial lesions in proximity to the eye, facial nerve, or other vital structure. Patients were selected for this therapy if previous medical management such as corticosteroids had failed, or if sufficient time had elapsed to allow spontaneous resolution or shrinkage of the lesion.

Interstitial Nd:YAG coagulation was performed with a bare quartz fiber (400- or 600-µm fiber) inserted through a 14-gauge angiocatheter, which was placed through the skin into the lesion (Figure 1). Power settings were between 15 and 25 W, with a pulse length of 0.3 to 1.0 seconds. Energy was delivered in a radial pattern, varying the depth of coagulation in accordance with the size of the lesion. The technique that we used for this study is similar to that described previously by Castro et al and Alani and Warren. Care was taken not to coagulate too superficially, as this would result in damage to the overlying dermis and epidermis. Treatments were repeated every 6 to 8 weeks until there was satisfactory reduction in the size of the lesion; this was often determined subjectively by the patient. We used general anesthesia for both the initial and the follow-up treatments in all pediatric patients.

Treatment results were monitored by measuring the change in size (area) of the lesion after treatment. Lesions were measured in square centimeters. The percentage of decrease relative to the size of the lesion at initial examination was calculated and recorded in a database. Lesions were photographed preoperatively and postoperatively to aid in monitoring of the results. A grading scale was devised to quantify the change in size and thereby allow comparison of results within our own study as well as with the results of other authors. On the basis of our observations during the study, the decrease in size of the lesions was categorized as 0% to 33%, 34% to 66%, or 67% to 100%.

Finally, data were collected on postoperative complications, cosmetic results, and patient satisfaction. Statistical analysis was performed with Statview 4.0 for Macintosh (Abacus Concepts Inc, Berkeley, Calif). A simple regression analysis was used to analyze the data. An unpaired, 2-tailed Student t test was used to compare results between patients according to the type of lesion: hemangioma vs vascular malformation. Mathematical transformation of the percentage change in area was performed to accurately assess the decrease in volume of these 3-dimensional vascular lesions. Since there was no control group for this case series, 95% confidence intervals were used to define the expected range of size change after treatment.

Of the 10 patients, 6 were male and 4 were female. Age ranged from 2 months to 16 years, with a mean of 40.3 months (3 3/5 years). Follow-up ranged from 2 to 39 months; mean follow-up was 13.1 months from the initial treatment. No patients became unavailable for follow-up during this study.

An average of 4.7 treatments per patient was required to obtain optimal results with the interstitial technique; this corresponds to an average of 33 weeks before the final outcome was achieved. The size at initial

RESULTS

lowed in most cases by a slow involution of the lesion. Biologically, hemangiomas behave like neoplasms with altered endothelial cell growth and proliferation.

Jackson et al described a classification system that expanded on the work of Mulliken and Glowacki. This classification system attempted to organize the lesions on the basis of treatment options and timing of intervention. They divided the lesions into hemangiomas, vascular malformations, and lymphatic malformations (lymphovenous malformation). Vascular malformations were further subdivided into low-flow lesions and high-flow lesions. They described treatment “with observation for hemangiomas, sclerotherapy with or without excision for venous malformations, embolization and excision for high flow, high shunt lesions, and resection for lymphovenous malformations.” Finally, they acknowledged the therapeutic challenge these entities present to clinicians.

This study presents our results with interstitial Nd:YAG photocoagulation of vascular malformations and hemangiomas. For the purpose of this study, the classification system of Mulliken and Glowacki was used. The objective of the study was to determine the efficacy of interstitial Nd:YAG photocoagulation for definitive treatment of both hemangiomas and vascular malformations.

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Figures

Figure 1. Technique of interstitial application of Nd:YAG laser energy for photocoagulation of hemangiomas and vascular malformations.
examination ranged from 3 cm² to 24 cm², with a mean lesion size of 9 cm². The overall mean reduction in size of the lesion was 53% (95% confidence interval, 33%-74%). No statistically significant difference between patients based on pathologic findings and response to treatment was suggested (\(P > .05\)), but the sample size was small, with only 2 patients having vascular malformation.

Treatment results were analyzed in terms of diminution in size of the lesion, as measured by appearance and physical examination. In these patients, medical management had failed and lesions had failed to spontaneously involute; thus, the only variable that could account for the observed shrinkage was the application of laser energy to the lesion. All patients showed a reduction in the size of their lesion, ranging from a 20% decrease to a 98% decrease. Five patients showed a decrease in size between 67% and 100%, another patient showed a 50% decrease, and the remaining 4 lesions decreased by less than 33% (Table and Figure 2). This decrease in the size of the lesion was noted during follow-up. Thus, the time course to improvement varied from patient to patient and also depended, in part, on the number of treatments required. Simple regression analysis showed no correlation between the percentage decrease in the size of the lesion and the amount of energy delivered to the lesion (\(P > .05\)). The histological changes related to interstitial photocoagulation with the Nd:YAG laser are demonstrated in Figure 3. Photographs that depict clinical response to treatment are shown in Figure 4 and Figure 5.

The response to treatment was observed clinically. Although preoperative MR images were useful for surgical planning, the study protocol called for postoperative MR imaging only in cases in which there was no response to treatment, or in which there was expansion of the lesion despite treatment. Since these results did not occur during the study, routine postoperative imaging was not performed.

Treatments were well tolerated. Good cosmetic results were noted with the interstitial technique, and no patient developed a disfiguring cutaneous scar. Patients were pleased with the overall results of treatment with the interstitial technique. In this series of 10 patients, there were no perioperative complications, including wound infection, pneumonia, allergic reaction, excessive intraoperative bleeding, postoperative lesion hemorrhage, or blood transfusion. Adequate analgesia was achieved with oral pain medication.

A number of treatment modalities may be used for hemangiomas and other vascular malformations. Options include observation and allowing time for spontaneous involute (which occurs with hemangiomas only), intralesional and systemic corticosteroid treatment,6 embolization,9,11 excision, electrolysis and thermocoagulation,13 immunomodulatory therapy with interferon alfa-2a,15 and laser photocoagulation.16,19 Recent interest has centered on interstitial delivery of laser energy to photocoagulate vascular lesions.6,7

### Table

<table>
<thead>
<tr>
<th>Patient No./Age</th>
<th>Lesion Description</th>
<th>No. of Laser Treatments</th>
<th>Average Energy, J</th>
<th>Other Treatment*</th>
<th>Results, % Decrease</th>
</tr>
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<tbody>
<tr>
<td>1/1 y</td>
<td>Hemangioma (tongue)</td>
<td>2</td>
<td>617</td>
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<td>75</td>
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<td>2/2 mo</td>
<td>Hemangioma (cheek)</td>
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<td>Intralesional corticosteroids, FEDL (3)</td>
<td>95</td>
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<td>Hemangioma (brow, forehead)</td>
<td>4</td>
<td>452</td>
<td>None</td>
<td>75</td>
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<tr>
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<td>110</td>
<td>Excision</td>
<td>20</td>
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<tr>
<td>5/6 y</td>
<td>Hemangioma (lower lip)</td>
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<td>Noncontact Nd:YAG</td>
<td>25</td>
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<tr>
<td>6/2 mo</td>
<td>Hemangioma (nasal tip)</td>
<td>5</td>
<td>728.5</td>
<td>FEDL (1)</td>
<td>25</td>
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<td>FEDL (5), noncontact Nd:YAG</td>
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<tr>
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<td>Hemangioma (temporal scalp)</td>
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<td>Excision</td>
<td>20</td>
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<td>992</td>
<td>Oral/intralesional corticosteroids</td>
<td>75</td>
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<tr>
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<td>Vascular malformation (upper lip)</td>
<td>4</td>
<td>416</td>
<td>FEDL (8), excision</td>
<td>75</td>
</tr>
</tbody>
</table>

*FEDL indicates flashlamp excited dye laser. Numbers in parentheses indicate the number of times the FEDL was used.

<Figure 2. Decrease in the size of the lesions after treatment with interstitial Nd:YAG photocoagulation (N=10).>

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into which category a patient will fall. Likewise, early intervention is recommended for lesions that may cause airway obstruction, hemorrhage and thrombocytopenia, or infection with tissue loss, or for lesions that threaten cardiovascular compromise.

For lesions that require therapy, a number of options exist, including medical and surgical interventions. Medical treatment for hemangiomas includes systemic and intralesional administration of corticosteroids. Most authors agree that the initial therapeutic modality should be a trial of systemic corticosteroids. Systemic corticosteroids carry well-documented risks, such as disseminated varicella and herpes infections, and some authors have questioned their efficacy. Indeed, Bartoshesky et al noted improvement in only 30% of patients treated with prednisone, 3 mg/kg daily, with an additional 40% having “some equivocal benefit.” They concluded that the role of systemic corticosteroid therapy in the setting of life-threatening or disabling lesions can be supported, but they cautioned against the routine use of corticosteroids for treatment of smaller, cosmetically displeasing lesions. They further cited major adverse effects in children, such as growth retardation and cushingoid characteristics, as evidence to support a conservative approach to management of pediatric hemangiomas.

Intralesional corticosteroid injection is an alternative to systemic corticosteroid therapy for hemangiomas. Kushner published his series using this technique in 1985. These pediatric patients with periorbital hemangiomas had a statistically significant response to the treatment without suffering local or systemic adverse effects. When patients are carefully selected, corticosteroids appear to be an acceptable first treatment for infantile hemangiomas; however, they are not helpful in the management of vascular malformations. As with systemic corticosteroids, the risks of treatment with local injection—such as embolization and occlusion of the central retinal artery—should be carefully considered.

For lesions that do not respond to corticosteroids, or for vascular malformations, surgical therapy is often necessary. Surgical options include excision and laser photoagulation. Excision may be complicated by extreme blood loss and disfiguring cutaneous scar; most au-
thors, therefore, prefer laser photoagulation. While the 585-nm flashlamp-pulsed dye laser works well on the superficial aspect of both hemangiomas and vascular malformations, the minimal depth of penetration by the beam does not allow the laser energy to reach the deeper aspects of these lesions. Therefore, laser modalities with more deeply penetrating beams have been used for deeper lesions.

Transcutaneous and contact applications of laser energy have been studied with the argon and Nd:YAG lasers. Shirk et al evaluated this method of energy delivery in a rat animal model. The results showed less tissue damage with use of the Nd:YAG laser. The disadvantage of transcutaneous applications is the potential for thick cutaneous scarring.

An alternative to transcutaneous delivery and contact mode is percutaneous application of laser energy. This method was designed to reduce the potential complication of scarring that can be seen with transcutaneous delivery. Alani and Warren used percutaneous laser photocoagulation with the Nd:YAG, potassium-titanium-phosphate (KTP), and argon lasers to treat hemangiomas and lymphangiomas. Reduction in the size of all lesions with all 3 lasers was noted, but no distinct advantage of one laser over the others in terms of wound healing was found. The authors concluded that percutaneous energy delivery is useful in bulky lesions that have potential for both excessive bleeding and unacceptable scar. They cautioned that close follow-up is necessary because lesions may expand after initially successful treatment.

Percutaneous (or interstitial) energy delivery by means of the Nd:YAG laser has been successfully applied to lesions other than hemangioma or vascular malformation. Castro et al reported treatment of a recurrent, unresectable epidermoid carcinoma of the neck. With MR imaging guidance, the lesion was treated with percutaneous phototherapy, resulting in a marked reduction in the patient’s intractable pain as well as arrested growth of the mass.

On the basis of the data from Castro et al, Alani and Warren, and Pushok et al, recent interest has centered on interstitial delivery of laser phototherapy for treatment of hemangiomas and vascular malformations. The focus of this investigation was to prospectively evaluate this technique as applied to 10 patients in 2 academic medical centers. Although there was no significant difference in the amount of energy required to effect improvement in the size of the lesion, all patients noted reduction in the size of their lesion. There was no significant difference in response to therapy based on pathologic findings, but the sample size is small, and this should be further evaluated in future studies. In addition, 1 year after treatment, no regrowth of the lesions was noted. All patients were pleased with their appearance after treatment. The advantages of this technique are clear: minimal complications, durable response to therapy, acceptable cosmetic results, minimal blood loss, decreasing vascularity of large lesions before surgical excision, and measurable shrinkage of lesions. Our study patients required an average of approximately 5 treatments to achieve the end result; this represents the only disadvantage of the interstitial technique.

Our results indicate that success with use of this technique for treatment of vascular lesions may be predicted on the basis of the flow velocity of lesions. In our study, lesions with a high flow velocity and with a larger feeding vessel (eg, facial artery, superficial temporal artery) tended to have less shrinkage of the lesion with time. In this study, lesions in the lip, nose, and scalp had less response to treatment than other regions. One of the patients in this series was treated with ligation of the facial artery. This patient had a hemangioma of the nasal tip supplied by a branch of the facial artery. These results suggest that ligation of the major feeding vessel may provide additional benefit in patients with lesions in high-flow vascular distributions. Adjunctive vessel ligation and/or embolization should be evaluated in future studies of patients who do not respond as expected to interstitial photocoagulation.

Radiographic imaging is indicated preoperatively in selected cases where large lesions may impinge on vital anatomical structures, such as the facial nerve or orbit. If treated lesions fail to respond or continue to enlarge, then repeated imaging would be indicated. None of the lesions in this series demonstrated this type of behavior, however. Although it was not used in this preliminary study, MR imaging can also be used for volumetric analysis of hemangiomas and vascular malformations.

Interstitial phototherapy for treatment of vascular lesions of the head and neck region in infants and children appears to be safe and efficacious in this preliminary study. More research in this area is indicated to further define the role of this promising technique. Interstitial photocoagulation is indicated for appropriately selected pediatric patients with hemangiomas or vascular malformations that have not responded to alternative treatment methods. In addition, residual lesions or large, nodular lesions may also benefit from this technique. Other indications for this procedure may become evident once the technique is studied further. Interstitial photocoagulation is contraindicated for lesions that have not been allowed to spontaneously involute, or have not had an adequate trial of noninvasive therapies. Treatment of lesions in the vicinity of the facial nerve, optic nerve, extraocular cranial nerves, trigeminal nerve, or other important anatomical structure is relatively contraindicated. Interstitial application is not appropriate for all hemangiomas or vascular malformations of the head and neck, and its use may be as an adjunct to other forms of treatment, such as corticosteroids and flashlamp-pulsed dye laser. However, when patients are carefully selected, this technique appears to have a role in reducing the size of residual hemangiomas and nodular vascular malformations.

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REFERENCES