Portable xenon arc light coagulator

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The short electric arc in xenon gas has been a source of energy for light coagulation for 16 years (Meyer-Schwickerath, 1960). Despite the usefulness of laser light in certain situations, the broad clinical indications for xenon arc coagulation have firmly established this modality as the workhorse with which the majority of light coagulations are done today.

FIG. 1 *Log-2
portable xenon arc
light coagulator*

The Log-2 portable xenon arc light coagulator (Fig. 1) was developed (O'Malley, 1971) in an attempt to simplify the operative procedure and to make this form of therapy more widely available. The key to the small size of this instrument is a parabolic reflector built into the lamp (Fig. 2). The reflector redirects the radiation so efficiently that a 150 watt lamp performs the same function as the 2,000 watt lamp in Meyer-Schwickerath's light coagulator. However, the reflector produces important differences in the configuration of the light beam delivered to the patient's eye. This instrument also differs from the Zeiss coagulator in several optical, electronic, and mechanical features. We examine here the

advantages and disadvantages of these new features, as revealed by 161 surgical procedures (Table I) carried out in the past 20 months on an unselected group of patients; 11,466 retinal and iris coagulations were applied in the course of this study.

FIG. 2 Bisected CX107 lamp (Photograph courtesy of EIMAC)

The Lamp

The lamp (Fig. 2) is a short electric arc in high pressure xenon gas and has essentially the same irradiation spectrum as the lamp in the Zeiss instrument. After passing through the optics of the instrument the spectrum consists of a continuum in the visible region with high spikes in the near infrared (Fig. 3) (Meyer-Schwickerath, 1960).

Table I Diagnosis of patients treated

Diagnosis	No. of surgical procedures
Diabetic retinopathy	108
Other diseases of the retinal blood vessels	14
Supplementary therapy on a pre-existing scleral buckle	13
Subpigment epithelial new vessels or bleeding	9
Retinal tear	8
Parafoveal presumed histoplasmosis	4
Changing shape or size of pupil	5
Total	161

FIG. 3 Spectral irradiance of arc after passing through optics of coagulator (Data by EG & G, Mass.)

The arc occupies the space between the electrodes. In each area of the arc the spectral irradiance is the same (Baum and Dunkelman, 1950) though the intensity differs considerably. The zone of maximal intensity is close to the cathode. This hot spot is at the focus of the reflector (Fig. 4) and its radiation is redirected parallel to the axis. However, the hot spot produces only 10 per cent. of the total radiant flux from the arc (Baum and Dunkelman, 1950). Other areas of the arc are out of focus to a greater or lesser degree and their radiation is divergent (Fig. 4). The net result is that a somewhat conical arc with an apical hot spot becomes an homogeneous "source", which is subsequently imaged on the target tissue (Fig. 5D, overleaf). The uniformity of the new "source" is such that, with the 6° coagulation aperture, the focused beam, measured with a Walsh Denschron, is only twice as intense at its centre as at near its edge. With small coagulation

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FIG. 4 *Radiation from hot spot redirected parallel to axis. Light from elsewhere in the arc diverges from the axis*

apertures, for which a smaller area of the "source" is being sampled, the difference in intensity between centre and edge is even less.

Such homogeneity contrasts with the Zeiss coagulator (Fig. 6), where a lateral view of the arc, together with its inverted image, is the "source" for coagulation. This arrangement results in two polar hot spots with a bright band between them and negligible irradiation elsewhere.

FIG. 6 *Coagulation "source" of Meyer-Schwickerath's light coagulator (6° size, 0.2 sec.)*

Delivery system

This consists of the lamp and its housing, the optical system, and the ophthalmoscope (Figs 5 and 7, overleaf). The entire unit weighs only 3 kg. and is highly manoeuvrable

FIG. 5 Diagram of light beam passing through optics of coagulator

FIG. 5A At the lamp window (0.04 sec.)

FIG. 5C At the pupillary diaphragm (8.5 mm. aperture, 0.04 sec.)

FIG. 5B At the shutter

FIG. 5D At the image field diaphragm—the "source" for coagulation (6° size, 0.2 sec.)

on an articulated arm. This mobility, enhanced by the freely rotating ophthalmoscope mirror, made it simple to perform all the operations with the surgeon comfortably seated.

At its exit from the lamp the light beam has a striking appearance (Fig. 5A) with the cathode and its support arms causing dense shadows. A slightly blurred image of these shadows is produced at the ophthalmoscope mirror. The cathode shadow covers the observation pinhole, eliminating glare due to light scatter by this window and by the neutral density filter which, during exposure, lies behind it. As a consequence one retains a crisp view of the patient's fundus during retinal exposure.

FIG. 7 Optical system

At the level of the pupillary diaphragm, the shadow from the cathode, though less well focused, is still quite dense (Fig. 5C). During coagulation the image of this diaphragm is focused at the patient's pupil so that the shadow of the cathode continues to aid observation by reducing light scatter and reflexes from the cornea and lens.

The image of the pupillary diaphragm, which is the narrowest point of the exit beam, must be centred in the patient's pupil, and the size of the diaphragm must be such that the output beam fits inside the pupil. Otherwise, some of the beam will fall on the iris and overheat the anterior segment (de Guillebon, Pfister, Govignon, Pomerantzeff, and Schepens, 1971). Furthermore, the energy absorbed by the iris is not available for retinal coagulation.

In clinical practice, it is a common mistake to select a pupillary diaphragm setting much larger than the patient's pupil. This compensates for placing the beam eccentrically as the pupil will still be uniformly illuminated and the retinal coagulations will be gratifyingly consistent. Unfortunately, this consistency is achieved at the expense of heating the anterior segment. To help counteract this tendency, the pupillary diaphragm of the portable coagulator is calibrated to show the diameter of its image at the level of the patient's pupil and the largest setting corresponds with a 9 mm. pupil. When the pupillary diaphragm matches the patients' pupil one, is forced to centre accurately; otherwise, a portion of the energy is lost on the iris and the retinal coagulations will not be consistent.

With the 156 retinal photocoagulations, care was taken to focus and centre the image of the pupillary diaphragm and to choose the proper iris diaphragm setting. The absence of iritis in the postoperative period may be the consequence of such caution.

At the pupillary diaphragm the light beam looks very much like that at the lamp window (Fig. 5C). There is a complex relationship between pupillary opening and transmitted energy. Most of the energy is concentrated in a ring with an inner diameter of 6.5 mm. and an outer diameter of 8.5 mm. This explains why, with a pupillary diaphragm setting of less than 5.5 mm., it was not possible to coagulate human retina, even in a heavily pigmented fundus.

The shutter is proximal to the pupillary diaphragm (Fig. 5B). When its perforations are focused and centred on the patient's cornea, the image of the pupillary diaphragm will be centred and focused at the patient's pupil.

The parabolic reflector, together with the condensing lens, produce an image of the arc at the image field diaphragm. This becomes the "source" (Fig. 5D) which is subsequently imaged on the target tissue. Various portions of this "source" are sampled by the apertures which range from 2° to 8° . Most patients were treated with the 4.5° and 6° apertures. The 3° and the 2° apertures were used close to the macula. The 8° aperture was reserved for the iris and the apex of high scleral buckles.

As described above, the "source" at the image field diaphragm is quite uniform. This is a unique feature of this instrument and probably accounts for the subtle ways in which its coagulations differ from those produced by the Zeiss instrument.

As might be expected (Meyer-Schwickerath, 1960), visible coagulation begins in the centre of the retinal target area and expands centrifugally. However, with the portable instrument coagulation is more easily confined to the outer retinal layers and there is a considerable margin of safety between a faint reaction and one which might be considered too heavy. This presumably explains why there was no detectable damage to the nerve fibre layer and no retinal vein rupture. As this was apparent early in the series, coagulations were subsequently placed across many retinal veins (Fig. 8). Despite this, there were only two instances of transient constriction of a vein. Nevertheless, one should probably continue to be cautious when giving treatment in the vicinity of retinal vessels.

On two occasions there was immediate bleeding from new vessels at the vitreo-retinal interface. In each case the bleeding was arrested by promptly pressing on the globe to raise the intraocular pressure and prevent the bead of blood from enlarging. The blood was then coagulated.

FIG. 8 Photocoagulation caused regression of new vessels at vitreo-retinal interface along inferior temporal arcade of 25-year-old diabetic's left eye, without apparent damage to retinal vessels

FIG. 9 Heavy coagulations. 18-year-old diabetic

The retinal coagulum looked like that produced by the Zeiss coagulator (Fig. 9), though usually less opaque. This difference is probably related to the uniformity with which the target area is heated.

The visible coagulum disappeared centripetally in 4 to 17 days, revealing stippled pigment epithelium surrounded by a narrow halo of depigmentation (Fig. 10). In subsequent months the central pigment became clumped or disappeared almost completely (Fig. 11).

FIG. 10A 8 days after an extensive barrage of coagulations for neovascularization due to sickle cell retinopathy

FIG. 10B 5 weeks later

FIG. 11 This 68-year-old man lost the macular vision of the left eye while on his honeymoon. 2 months after photocoagulation of a parafoveal, sub-pigment epithelial vascular membrane his vision is 20/40

Power unit

This weighs a mere 20 kg. and is run off regular household current (110 or 220 v), so that the instrument may be used wherever desired. Such mobility has proven useful, particularly for patients with retrovitreal blood. Two such patients were treated in their hospital room after 12 hours rest in bed with binocular patching had allowed the blood to settle.

The electronic timer, with a range from 0.1 to 3.0 sec. (Fig. 12), automatically controls the exposures. The timer was a welcome feature, for most of the coagulation times were shorter than 0.5 sec., too fast for accurate control by the surgeon's reflexes.

FIG. 12

Experiments on pigmented rabbits (Fig. 13), together with clinical experience, have shown that, just as with the Zeiss instrument (Meyer-Schwickerath, 1960; Geeraets, Williams, Ham, and Guerry, 1962), retinal exposures should be brief so as to minimize the total energy dosage. With the 4.5° and 6° apertures of the portable coagulator, one may continue the exposure up to 0.8 sec. and still retain a satisfactory ratio between energy input and clinical effect. By contrast, the Zeiss exposures should not be longer than 0.4 sec. The explanation for this difference is that only part of the target area is illuminated intensely with the Zeiss instrument (Fig. 6), whereas with the portable coagulator the entire area is exposed.

Whenever possible, exposure times of 0.2 to 0.4 sec. were used for coagulating retina. While treating iris, as the aim was to shrink the tissue, longer times (0.4 to 1.0 sec.) were chosen.

The power level is controlled by a dial (Fig. 12) which is adjusted precisely to the needs of the individual patient. The radiant output triples between settings 0 and 10 (Table II).

Deductions made from data on pre-existing continuous wave xenon coagulators, the light "source" of which is not homogeneous, combined with experiments on rabbits, led to the initial choice of an inadequate power output. Thus, of the first 115 operations, the top power setting was used in 42 cases and the lower half of the power scale was used only sixteen times. Furthermore, on six occasions, it was necessary to use exposure times

Table II Output relative to input and image field diaphragm (Iris aperture 8 mm.)

Image size	Input power					
	0	2	4	6	8	10
2°	1.6	2.2	3.1	3.5	4	4.3
3°	5.2	8.2	11.1	13.2	14.5	15.5
4.5°	12.6	19	29.5	34.5	36	41
6°	29.5	47	66	79	93	100

(Data furnished by Clinitex)

FIG. 13 Typical experimental finding on a rabbit, showing exposure times and power settings required to give consistent retinal coagulations

greater than 0.8 sec. and in one patient the retina could not be coagulated. The instrument was consequently modified to increase the power unit. Since then, 46 cases have been treated using exposure times of 0.1 to 0.5 sec. and power settings ranging from 2 to 8. We now seem to have an appropriate power range for this patient population which, with two exceptions, is composed of mixed European stock.

Ametropia

During light coagulation, contact lenses (Meyer Schwickerath, 1960) are theoretically the best way to correct optical errors. Unfortunately, they cause overheating of the anterior segment (de Gillebon and others, 1971) and are awkward for treating in the periphery. The alternative is to place the corrective lens elsewhere in the light pathway.

Hyperopia, whether idiopathic, due to aphakia, or due to scleral indentation, is best corrected by placing the auxiliary plus lens between the tip of the cone and the ophthalmoscope mirror. With the lens in this position, the wide angle of the original observation system is retained, the beam diameter is reduced so that one can use a wider iris diaphragm setting, the manoeuvrability of the instrument is unchanged, and the surgeon's second hand is free.

These auxiliary lenses were used for three aphakic patients with diabetic retinopathy, eleven patients with inadequate chorio-retinal adhesion after scleral buckling, and two patients in whom scleral depression was used to reach a peripheral lesion. All patients showed appropriate retinal reactions, though one of these treated on a scleral buckle developed a re-detachment notwithstanding the treatment.

When correcting myopia, it is impractical to place a minus lens in this same position, for the light beam becomes too wide, requiring an excessively small pupillary diaphragm setting. To avoid this, the auxiliary minus lens is hand held close to the patient's eye. To increase manoeuvrability and to avoid misting, these lenses are just large enough to

accommodate the light beam. The disadvantage of the hand-held lens is that the surgeon's second hand is no longer free.

Surface coagulation

For iris coagulation a convex lens of short focal length is suspended in the light path distal to the ophthalmoscope mirror. This produces on the iris a small image of the light "source" at the image field diaphragm. The reaction is observed through the condensing lens so that one has the high magnification necessary to focus precisely and thus avoid overheating adjacent tissues (Burns, 1965). The disadvantage of such magnification is that the field of view is small.

This attachment was successfully used to shrink aphakic areas of the iris in five patients. The indications were to move an eccentric pupil into the visual axis (2), to decentre the pupil away from the edge of a dislocated lens (1), or to enlarge a miotic pupil (2) (Straatsma, Allen, Pettit, and Hall, 1966; Cleasby, 1970). The 6° and 8° apertures were used. The pupillary diaphragm was wide open. The power settings varied from 1 to 10 and the exposure from 0.4 to 1.0 sec. A saline bath was used to protect the anterior segment. The iris was shrunk and the pupil was modified appropriately in each case.

Summary

This clinical trial of the Log-2 portable xenon arc light coagulator shows it to be fundamentally the same as Meyer-Schwickerath's Zeiss instrument.

The principal difference between these instruments is the uniformity of the coagulation "source" in the Log-2. Theoretical considerations and the present, admittedly limited experience suggest that this is advantageous.

This instrument is small and easy to handle. The observation system is very clear, the supplementary electronic controls are helpful, and it is a distinct advantage that it can be run on regular household current.

The disadvantages are that the patient's pupil must be wider than 5.5 mm., the 2° image field aperture cannot always be used, and a very fair patient with hazy media may not develop a retinal coagulum.

Sincere thanks to Clinitex, who have been so patient in developing the coagulator, and to EIMAC, a division of Varian, who have been equally patient in developing the lamp.

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