Radioactive plaque brachytherapy has become the standard of care for treatable choroidal melanomas. The COMS trials\textsuperscript{1,2} established this as acceptable globe-sparing therapy for medium sized melanomas (6.0–16.0 mm basal diameter, 2.5–10.0 mm apical height), and since that time those treatment guidelines have been stretched to treat even larger tumors. The principle used to treat these tumors involves exposing the highly mitotic cells to ionizing radiation from proximally placed implants. These implants are coin-sized gold plaques loaded with carefully dosed radioactive pellets, most commonly iodine-125 or palladium-103 (Figure 1). The mechanics of the disbursement of the radiation is well understood, so that a precise amount of intense radiation is delivered to a known area over a predetermined number of days while a comparatively very low dose is delivered to adjacent normal tissues. This is a great advantage over external beam or charged particle radiation treatments, which cause greater damage to anterior segment structures.\textsuperscript{3}

The radiation dose for radioactive plaques is calculated based on the thickness of the melanoma and the known properties of the medium through which it will travel (sclera and tumor). The appropriate number and arrangement of pellets is determined based on the apical thickness of the tumor. A plaque is selected to more than cover the largest basal diameter of the lesion. The plaque dimensions are in even numbers from 10 mm to 22 mm, and it is recommended that there be a 2.0 mm overlap on each side (Figure 2). Therefore, the largest

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**Ultrasound-guided Plaque Placement for Choroidal Melanoma**

A tutorial of a technique that allows immediate intraoperative verification and documentation of plaque placement.

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**Figure 1.** Gold plaque loaded with iodine-125 pellets. Side shown is approximated to the surface of the globe and sutured in place using eyelets indicated by forceps tip.

**Figure 2.** Appropriately placed plaque extending past lesion margins. Blue arrows indicate plaque margins.
basal diameter is rounded up to the nearest even number and 4.0 mm is added to arrive at the necessary plaque size.

Given that the dimensions of the tumor are carefully considered when constructing the plaque, it is important to orient the plaque directly opposed to the lesion and completely cover the margins. Suboptimal plaque placement could result in subtherapeutic levels of radiation to the apex of the tumor, and failing to include the margins within the plaque edge will leave untreated areas of malignancy that allow disease progression. Additionally, once the plaque is implanted, extraocular muscles can interact with it, or the plaque can be shifted too posterior, causing it to slide down the optic nerve cord and inducing a tilt (Figure 3). As a result, improperly directed radiation could harm adjacent tissue, increasing the risk or severity of side effects. For these reasons, it is crucial to locate the plaque with precision and understand how it fits in the patient’s orbit.

Methods for plaque placement are fairly straightforward and vary widely based on surgeon preference. The primary technique used at our center involves transillumination of the lesion and marking of the visible tumor margins and/or suture holes on the edge of the plaque following a conjunctival peritomy. The plaque is then placed to best cover the margins, matching the suture hole markings. This technique can demonstrate the proximity of the plaque to the lesion and allow reliable placement, but it is not always easy to visualize all aspects of the tumor, and suturing can allow shifting of placement. Very posterior tumors are especially difficult to transilluminate and more difficult to plaque in general, which may explain why treatment failure is more commonly reported in this location.4

Variations on this technique include direct visualization of the lesion while manipulating the posterior sclera using a marking depressor, use of a light-pipe to transilluminate around the plaque,5 or use of a light source mounted on the plaque itself.6 Postoperative echography was described for plaque placement confirmation as early as 1988,7 and other imaging modalities such as MRI are also used.8 Ultrasound is widely used in ophthalmology. For ocular oncology it is used to diagnose and categorize lesions based on size and echogenicity and to monitor the size of the lesions after treatment.9 In addition to being used postoperatively to confirm plaque location, its use has also been described intraoperatively10,11; however, this use is not currently universal.
TECHNIQUE

The technique for ultrasound-guided plaque placement is simple but requires understanding of proper probe positioning as well as of the clock hours displayed on the resulting echogram. Because this must be performed under sterile conditions, the ultrasound probe and cord are covered with a probe drape (Surgi Transducer Cover, Ref 610-664; Civco, Kalona, Iowa) under sterile conditions, with conduction gel both inside and outside the drape where the probe face will rest. Care must be taken that there is no air between the probe and the drape, as well as between the drape and the eye, that would interfere with sound conduction. The eye is manually rotated so that the gaze is toward the clock hour of the lesion, away from the probe. The probe is placed on the sclera opposite the lesion so that it is centered in the echogram, and gain is adjusted for maximum resolution. Transverse and longitudinal probe positions are performed to check for adequate plaque placement (Figure 4), and the scan line is swept back and forth over the lesion in each position to ascertain that the plaque extends past all tumor borders. If the plaque placement appears suboptimal, the echographic findings can be used to determine the direction the plaque should be shifted in order to achieve desired positioning.

Standardized B-scan protocol dictates that for transverse scans, which scan the lateral aspect of the lesion, the marker (usually a line or dot on the probe handle near the probe face) should be directed parallel to the limbus, either superior or nasal in orientation depending on the area of interest.12 This provides for the clock hour in the center of the scan line, and therefore of the echogram itself, to be that of the lesion. The marker

Figure 5. Technique for transverse (lateral) ultrasound-guided plaque placement for a tumor at 10 o’clock, with the probe positioned opposite at 4 o’clock and the marker oriented superiorly in this oblique angle (A). The corresponding scan shows the 10 o’clock tumor to be centered in the scan line, with 1 o’clock at the top and 7 o’clock at the bottom, and the plaque initially decentered superiorly (B), indicating that it should be shifted away from the marker orientation, toward 7 o’clock. After adjustment, the plaque now appears optimally positioned (C). Blue arrows indicate plaque margins. Yellow arrows indicate tumor margins.

Figure 6. Technique for longitudinal (radial) ultrasound-guided plaque placement for a tumor at 1:30, with the probe positioned opposite at 7:30 and the marker oriented directly toward the lesion at 1:30 (A). The corresponding scan shows the lesion to be centered in the scan line, with 1:30 anterior at the top and the optic nerve shadow at the bottom, and the plaque initially decentered superiorly (B), indicating that the plaque needs to be shifted more posteriorly along that meridian. After adjustment, the plaque now appears to be optimally positioned (C) for adequate treatment. Blue arrows indicate plaque margins. Yellow arrows indicate tumor margins.
A misplaced plaque can result in treatment failure. Therefore, every effort must be made to ensure adequate positioning.

orientation represents the clock hour at the top of the echogram, and the clock hour opposite the marker is represented at the bottom, each approximately three clock hours from that of the center. Hence, should the plaque be too inferior in the image, it should be shifted toward the clock hour represented by the marker. If the plaque is too superior in the image, it should be shifted away from the clock hour represented by the marker. In the example shown in Figure 5, the lesion is centered at 10 o’clock in the right eye. Therefore, with the gaze of the eye directed toward 10 o’clock and the probe held opposite at 4 o’clock (Figure 5A), the lesion is centered in the image. The marker is directed toward the superior aspect of that angle, or 1 o’clock; hence, the clock hour opposite the marker is 7 o’clock. The plaque is seen to be placed too superiorly in the image (Figure 5B), and therefore it should be shifted away from the marker orientation toward 7 o’clock to achieve optimal positioning (Figure 5C).

For longitudinal scans, which scan the radial or anterior/posterior aspect of the lesion, only 1 clock hour is displayed on the echogram from anterior to the top to posterior at the bottom, where the optic nerve shadow is visible. The marker is now directed perpendicular to the limbus, directly toward the clock hour of interest. Because this verifies the anterior/posterior placement of the plaque, if it appears too inferior in the image, the plaque is too posterior and should be shifted more anteriorly along the clock hour of interest. If the plaque appears too superior in the image, it is too anterior and must be shifted posteriorly along the specified clock hour. In the example shown in Figure 6, the lesion is centered at 1:30. The gaze of the eye is directed toward 1:30 with the probe held opposite at 7:30. The marker is directed perpendicular to the limbus toward 1:30 (Figure 6A). The plaque is seen to be too superior in the image (Figure 6B), so therefore it must be shifted posteriorly toward the nerve to achieve optimal positioning (Figure 6C).

Both the transverse and longitudinal aspects of the placement are continually checked, with the plaque shifted and resutured as indicated, until the tumor appears well centered and the edges of the plaque appear to extend past all tumor borders as desired.

CONCLUSION

A misplaced plaque can result in treatment failure. Therefore, every effort must be made to ensure adequate positioning. With proper knowledge of the technique, ultrasound-guided plaque placement serves as an efficient and reliable method for immediate intraoperative confirmation of appropriate plaque placement or a guide to necessary modifications. In addition, intraoperative ultrasound imaging provides documentation of adequate plaque placement at a significantly reduced cost compared with MRI. Because of this, our institution encourages widespread adoption of intraoperative ultrasound to assist and verify plaque placement.

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