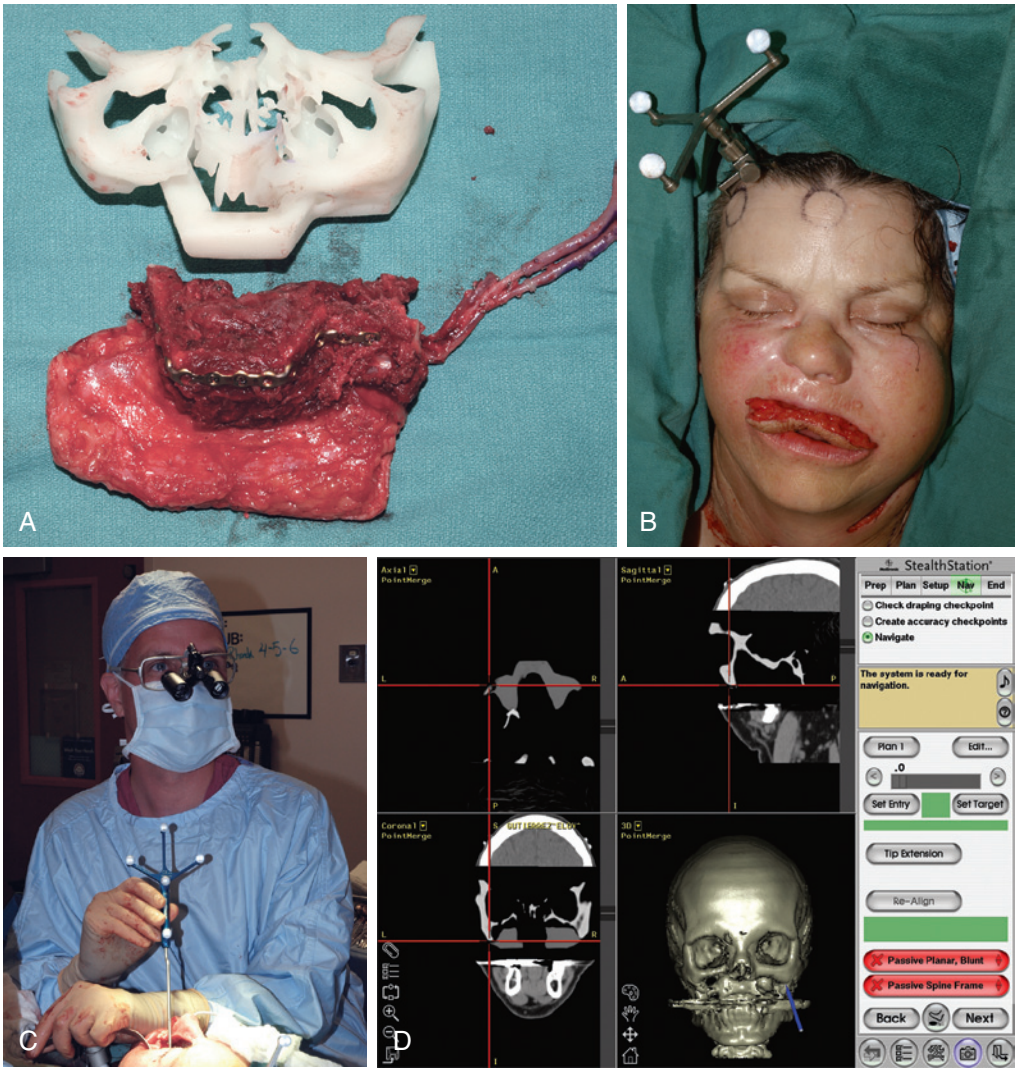

Figure 4.6 (A) Midfacial reconstruction with a fibula free flap using a rapid prototype model to guide shaping. (B) Inset of the flap is performed transorally, without facial incisions. Correct flap positioning prior to rigid fixation is confirmed using stereotactic navigation, which requires a fixed array so that the system can locate the facial skeleton in 3-dimensional space. (C) A handheld probe is used to confirm that the flap is in the planned position. (D) The tip of the probe can be located on the patient's computed tomography (CT) scan in multiple planes. Note the virtual fibula flap has been superimposed on the CT scan images.

VectorVision (BrainLab, Westchester, IL). All of the systems utilize some type of sensor, either optical or electromagnetic, that is carried on a probe as well as fixed on the patient. Optical systems are utilized for reconstructive surgery, since electromagnetic systems require special instrumentation. Standard metallic instruments disrupt the electromagnetic field and result in tracking inaccuracies. The main disadvantage of optical systems is that a direct line of site must be maintained between the infrared-emitting diodes on the patient and probe, and the infrared sensors connected to the CPU.

Intraoperative navigation for reconstructive surgery is best performed using a rigidly fixed mobile array rather than a headset or frame, since the head must be able to turn freely during surgery. The infrared cameras are used to detect the patient's position based on reflectors connected to the mobile array, which is rigidly fixed to the calvarium at the start of surgery. The probe, essentially a wand with reflectors on it for localization with infrared light-emitting diodes, is used to confirm positioning by acting as a handheld pointer whose tip location is mirrored on the screen of the computer unit (Fig. 4.6). Prior to use, a registration procedure in which the virtual patient on the computer workstation and the actual patient are overlapped by localization of at least three reference points with the probe. If the inset is not accurate, then it can be readjusted and positioning again checked against the virtual ideal.

ASSESSMENT OF TISSUE PERFUSION WITH INDOCYANINE GREEN ANGIOGRAPHY

Indocyanine green (ICG) is a non-toxic contrast agent that is bound to protein in plasma. Laser-assisted ICG angiography (Spy Elite System, LifeCell Corp., Branchburg, NJ) is an

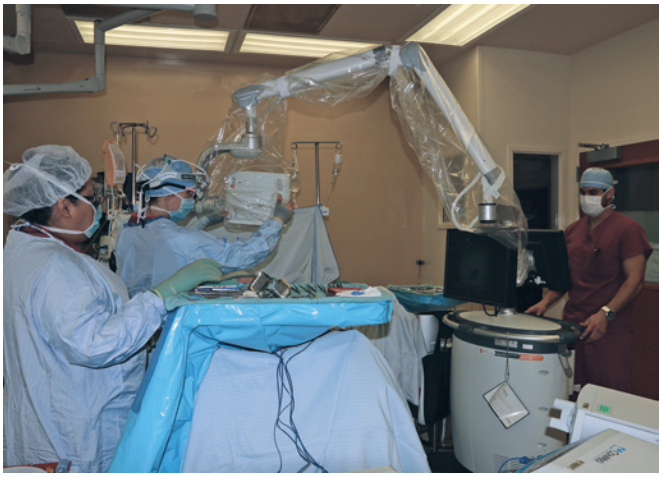

Figure 4.7 Indocyanine green (ICG) intraoperative angiography system (Spy Elite System, LifeCell Corp., Branchburg, NJ). A sterile drape allows the surgeon to position the laser light source.

imaging modality that provides real-time imaging of tissue perfusion, in which an 806 nm laser light source is used to induce fluorescence with a peak at 830 nm of the ICG dye that is captured on a charge-coupled camera with filters that block out ambient and laser light (Fig. 4.7). Common uses of ICG angiography include assessing viability of random, pedicled, and free flap tissues, assessing perforator location to aid in the design of perforator flaps, and predicting mastectomy skin necrosis in implant and autologous tissue breast reconstruction. Additionally, ICG plays a role in the diagnosis and microsurgical treatment of lymphedema by allowing the surgeon to visualize subcutaneous lymphatics when injected subcutaneously and picked up by the lymphatic system. Most of the published data involving ICG "lymphography" has involved the use of another system, which utilizes an infrared light emitting diode light source coupled with a handheld (rather than arm-mounted) camera (Photodynamic Eye; Hamamatsu Photonics K.K., Hamamatsu, Japan). There have been no studies comparing the two systems, however, both systems allow visualization of dye in real-time as well as a review of video capture.

ICG has an excellent safety profile, having been used to measure cardiac output, assess hepatic function, and for ophthalmic angiography for over 40 years. There is a small risk (0.17%) of adverse drug reaction, including anaphylaxis in subjects allergic to iodides, which are present in the injectable product.[10] ICG is excreted by the liver with a half-life of 3–5 min. Because of the short plasma half-life, multiple evaluations can be performed during the same operative procedure. ICG is widely available (IC-Green, Akorn, Inc., Lake Forest, IL) and of low cost when used with the handheld near-infrared camera. However, the Photodynamic Eye is not available at this time in the USA. The Spy Elite System is available in the USA and is packaged with sterile drapes that allow handling of the imaging system during surgery. Other than cost, another disadvantage of ICG imaging is the time needed to perform it intraoperatively, which typically requires 15–20 min in most situations.

FREE FLAP PERFUSION

Early reports described using ICG angiography to assess first cardiac bypass, then later free flap anastomoses. ICG angiography can be very accurate when used to verify the patency of an anastomosis that is questionable. The dye, injected via a peripheral IV, can be seen crossing first the arterial anastomosis, then the venous anastomosis shortly afterwards. Imperfections or blockages along the anastomotic suture line can be readily visualized. For practical purposes, most of the time this is not necessary, since signs of anastomotic failure are usually readily apparent clinically. However, in cases of partial obstruction due to an accumulating thrombus at the anastomosis or around an intimal tear, ICG angiography may theoretically be of benefit when other clinical findings are equivocal.

More commonly, ICG angiography is used to assess blood flow to the skin paddle of pedicled and free flaps to ensure its adequacy (Fig. 4.8). If ICG dye does not accumulate in a portion of the flap skin paddle, generally within 2 min or less following intravenous injection, it suggests that that this portion of the skin will ultimately be non-viable. Generally about 5 mL of ICG is injected, then the skin is observed on the imaging system monitor, while the camera is focused on the skin flap. Tissue that demonstrates subjectively questionable perfusion on black and white imaging is examined clinically for signs of hypoperfusion. In this way, partial flap loss is decreased.

Another related technique is to use ICG angiography to determine which or how many perforators are necessary to avoid partial skin flap loss or fat necrosis. In this case, multiple perforators are dissected then individually temporarily occluded with microvascular clamps, except for the perforator or perforators that the surgeon plans to use. Blood flow to the skin flap is then analyzed by ICG imaging. If the skin flap appears well perfused, then the temporarily occluded perforators can be divided. If the skin flap appears hypoperfused after about 2 min following injection, then additional clamp(s) are then released until the entire flap appears adequately nourished. This second technique has mostly been utilized to analyze deep inferior epigastric artery perforator (DIEP) flap perforator flow, but has also been reported for various flaps used in head and neck reconstruction, such as the anterolateral thigh and fibula free flaps.[11]

In addition to the black and white video image captured by the charge-coupled camera, the Spy Elite system comes bundled with analysis software (SPY-Q). The software features two options for quantitative measurement of the fluorescence recorded on the video images. The first option is a relative percentage technique, which reports the fluorescence of selected areas of the image relative to a user-defined reference point that is designated as 100% perfusion. This reference point is subjective and can lead to values that are above 100% if the brightest portion of the image is not selected as the reference point. The second method is an absolute measurement that uses a 255-level grayscale and assigns a point value to selected areas of the image that correspond to the signal intensity. In this scale, a value of 6.0 is considered the lower limit of acceptable perfusion.[12]

Wu et al.[13] reported a 14% false-negative (specific area of the flap looked viable by ICG angiography, but resulted in necrosis) rate and a 9% false-positive (specific area of the