

DIEP Flap Preoperative Planning Using Virtual Reality Based on CT Angiography

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Deep inferior epigastric perforator (DIEP) flap surgery is an excellent reconstructive tool for both immediate and delayed reconstructions of the breast.¹⁻³ Currently, computer tomography angiography (CTA) with computer generated 3D postprocessing is the “gold standard” for locating DIEA perforators.^{4,5} However, both CTA and magnetic resonance angiography (MRA) lack the ability to clearly visualize the intramuscular course and vessel distribution in the fat tissue.⁶

During surgery, confronting a tortuous and long perforator in the muscle requires a further delicate dissection, leading to longer operative times, with higher risks of postoperative complications.⁷ The need to know the vessel’s course preoperatively is the impetus for developing an improved imaging technique for vessel course characterization, using augmented reality (AR) and virtual reality (VR) systems. While AR overlays digital information on objects or scenes in the real world, VR immerses the user in a completely simulated world.⁸ VR can enhance anatomical 3D visualization, allowing surgeons to very clearly grasp the vascular anatomic complexity.

The main goal of Amplifier VR in DIEP planning is to provide the best and fastest visualization of perforators in the abdominal wall for plastic surgeons (see **Video [online]**, which demonstrates a new VR imaging system based on a CT angiogram called Amplifier VR that provides a 3D simulated experience). The Amplifier VR algorithm is based on machine learning and methods of statistical analysis, which allows transforming computer tomography scans into patient-specific 3D reconstructions. The algorithm scans the CT and detects subcutaneous fat and muscles of the abdominal wall with high sensitivity and specificity (above 95%). Based on the analysis of densities within these structures, the algorithm selectively removes

fat and muscle from the reconstruction, maximizing the visualization of perforators. Algorithms that are based on direct identification of blood vessels, which are used by other systems, have more chances for artifacts and obtain less accurate results.

Amplifier VR has created a platform that allows surgeons to see this reconstruction in VR and intuitively control it in space, and has provided a set of simple tools for preoperative planning. The system uses a head-mounted display (HMD) with stereoscopic glasses and two hand-held remote controls. This allows the user to look and move around for the stated purpose of preoperative surgical planning.⁹

We believe that this system will increase accuracy in surgical planning and reduce operative times. The VR headset projects an image via an inside display onto the eyes. The HMD combines VR with an inertial measurement unit (IMU) device that measures and reports a body’s orientation in space to construct a realistic virtual environment in 3D. Amplifier VR’s software allows an alternative visualization of medical digital imaging and communications in medical (DICOM) data, with the ability to access more information per pixel and virtually manipulate the patient’s scans.

Furthermore, we developed for the Amplifier VR a specific and optimal high-resolution CT angiogram scan protocol (fine slices 0.5–0.75 mm) based on the latest dual source technology from Siemens (Force CT scanner) and the use of intravenous high concentration iso-osmolar contrast media, Lomeron 400. This protocol allows for the best visualization of small blood vessels within the fatty tissue and muscles while allowing patients to be scanned with a minimal radiation dose and with minimal IV contrast. Vles et al.⁷ systematically reviewed the use of AR and VR technologies in plastic surgery. However, studies on VR technology were lacking. Regarding AR, its preoperative use was shown to identify perforators more accurately than Doppler ultrasound together with a reduction in operative times.

Using this system, preoperative measurements can be taken by the surgeon unassisted, without the aid of a radiologist. The surgeon can then build a tailored surgical roadmap and avoid expectancy in anatomical variations unforeseen by current imaging modalities.

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We postulate that preoperative planning by the new Amplifier VR tool can increase a surgeon's understanding of the patient's individual anatomy and facilitate the complex task of choosing the optimal perforator for flap harvest. Using the Amplifier VR system allows the surgeon to rank the perforator diameter, its distribution in the fatty tissue, and visualization of the intramuscular course (short or torturous), and to visualize DIEP, where an artery is located and if its size is fit for use. Last, this system allows for measuring the exact coordinates of the chosen perforators in relation to the umbilicus as they exit the muscle.

Two more advantages of the Amplifier VR system are having the option of global collaboration by allowing multidisciplinary teams into the same virtual environment and that Amplifier VR allows for thorough, rapid and kinesthetic manipulation of a patient's anatomy, facilitating the development of microsurgical training, especially for young surgeons.¹⁰

The current use of VR and AR in surgical planning is in its early stages, not yet widely available in standard clinical care. However, it seems to be a promising tool to be used in the near future in a more extensive manner.

Each patient's unique anatomy dictates the choice of perforators for flap-based reconstruction, which makes preoperative mapping of the vascular anatomy essential. Virtual technology solutions provide additional information that can open new possibilities in clinical practice and education. Amplifier VR immerses the user in the exact, sometimes tortuous, vasculature by giving the sensation of directly viewing and manipulating human anatomy. Amplifier VR's software offers a full-scale tool list that allows physicians to see and manually manipulate a patient in ways that can only be done within a virtual environment. Immersion is a key element of the virtual setting, and Amplifier VR's intuitive interaction allows for

the development and improvement of the operator's surgical performance.

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