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Breast

3-DIEPrinting: 3D-printed Models to Assist the Intramuscular Dissection in Abdominally Based Microsurgical Breast Reconstruction

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Summary: Harvest of the deep inferior epigastric vessels for microsurgical breast reconstruction can be complicated by an intricate and lengthy subfascial dissection. Although multiple preoperative imaging modalities exist to help visualize the vascular anatomy and assist in perforator selection, few can help clearly define the intramuscular course of these vessels. The authors introduce their early experience with 3D-printed anatomical modeling (to-scale) of the infraumbilical course of the deep inferior epigastric subfascial vascular tree to better assist in executing the intramuscular dissection. *(Plast Reconstr Surg Glob Open 2019;7:e2222; doi: 10.1097/GOX.0000000000002222; Published online 25 April 2019.)*

INTRODUCTION

The deep inferior epigastric perforator (DIEP) flap and muscle-sparing transverse rectus abdominis myocutaneous flap are the workhorses of microsurgical breast reconstruction.[1,2] Flap survival relies on the identification and harvest of reliable vessels.[3] Although suitable perforators can be appreciated intraoperatively, these often take a tortuous course through the rectus abdominis.[4] Intramuscular dissection of the pedicle becomes time-consuming and potentially dangerous. Although preoperative imaging helps anticipate difficulties, new technologies give way for advancements in surgical planning.[5–7]

Three-dimensional (3D) printing has risen to vast applicability within plastic surgery.[8] This technology affords tremendous advantages for customizing prostheses and implants.[9,10] In craniomaxillofacial surgery, 3D printed preoperative and postoperative models are now integral to surgical planning for complex deformities.[11] Three-dimensional printing can also be utilized as an educational tool that can transform 2-dimensional anatomy into life models.[12] It only seems logical to now employ 3D-printed anatomic models for enhancing microsurgical breast reconstruction.

Advancements in Preoperative Imaging for Microsurgical Breast Reconstruction

Multiple modalities exist for preoperative assessment of the abdominal vasculature. Computed tomography angiography (CTA) has been hallmarked with reduced surgical time, improved flap viability, and a better surgeon operative experience.[6] Similar results have been reported for magnetic resonance angiography, without exposure to ionizing radiation.[5,13] Doppler ultrasonography has also been considered as a noninvasive approach, further advanced by color duplex visualization of real-time flow.[14] Imaging has now been brought into the operating room with real-time indocyanine green angiography.[15] Recent application of the smart phone compatible FLIR ONE (FLIR Systems, Inc., Wilsonville, Ore.) miniature thermal camera pre, intra, and postoperatively facilitates perforator identification, execution of the dissection, and flap monitoring, respectively.[16-18]

Although these imaging modalities have been rightly celebrated for their ability to reliably identify optimal perforators, the authors feel that finding reliable perforators

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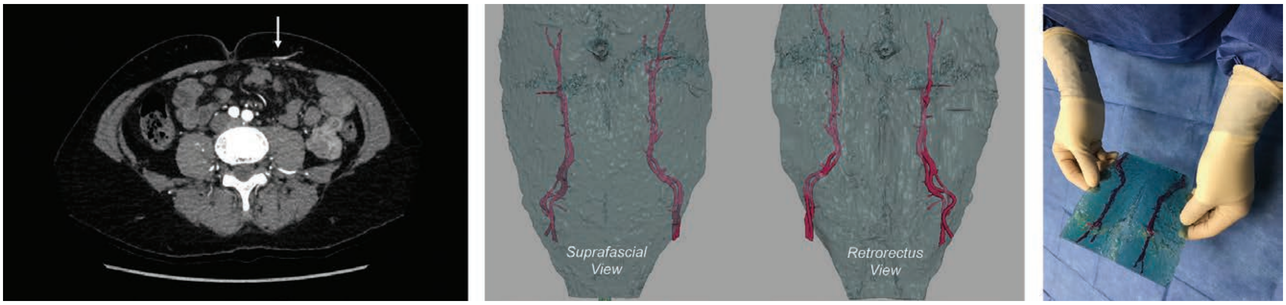


Fig. 1. Steps for 3D-model creation. A, A preoperative computed tomography angiography (DIEP protocol) is used to create a 3D-printed model of the infraumbilical course of the deep inferior epigastric subfascial vascular tree in conjunction with the 3D and Quantitative Imaging Team within the Department of Radiology. B, DICOM to PRINT-3D Systems (Rock Hill, S.C.) segmentation software is used to develop premodel proofs created via collaboration between the engineers and surgical team. C, The 3D model is printed within the Stratasys (Eden Prairie, Minn.) Connex J735 and ready for intraoperative use to safely guide the intraoperative dissection.

intraoperatively (with or without imaging) has never been the ultimate challenge to harvesting abdominally based free flaps. Rather, it is the inability to clearly conceptualize the subfascial intramuscular course of the deep inferior epigastric vascular tree that has been of a greater challenge. The authors introduce their early experience with 3D-printed anatomical modeling (to-scale) of the infraumbilical course of the deep inferior epigastric subfascial vascular tree to better assist in executing the intramuscular dissection.

Technique: Creating the 3D Anatomical Model

A preoperative high-resolution mixed arterial-venous phase CTA of the abdomen and pelvis is obtained to highlight the perforating vessels of the deep inferior epigastric system below the umbilicus (Fig. 1A). Once complete, an order is placed to the 3D and Quantitative Imaging Team within the Department of Radiology at our home institution to request a 3D-printed anatomic model for treatment planning.

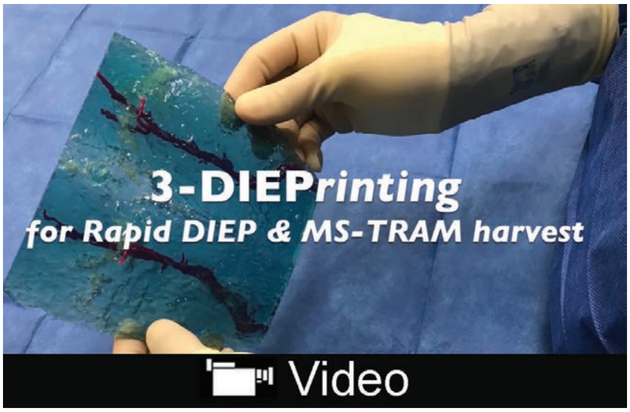
DICOM to PRINT-3D Systems (Rock Hill, S.C.) segmentation software is used to develop premodel proofs created via collaboration between the engineers and surgical team. Because the subfascial anatomy is of most interest, the process begins by using level thresholds to create isolated masks of the perforating-source vessels as they course through the rectus abdominis muscles. Lateral communicating intercostal vessels are included when possible. These masks are trimmed and verified against the CT data, then exported into the .STL 3D file format (Fig. 1B).

Once the proofs are approved, the 3D model is printed within the Stratasys (Eden Prairie, Minn.) Connex J735. This printer utlilizes Polyjet technology (jetting of photocurable liquid droplets that are cured via UV light) incorporating up to 6 different materials at a time. This system can print multiple colors within the same model, allowing representation of the perforating-source vessels in magenta coursing through a semitransparent blue rectus abdominis muscles (Fig. 1C).

From the time the order is placed to the 3D and Quantitative Imaging Team, a 3D anatomic model (to-scale) can be printed and ready for intraoperative use within 48–72 hours. The model was wrapped in a clear semiocclusive dressing to be safely handled on the operative field (Fig. 2).

DISCUSSION

The authors offer a novel use of 3D-printed anatomic models to streamline the intramuscular dissection of abdominally based free flaps. Intraoperatively, surgeons can pick up, manipulate, and view the model from multiple vantage points. The added tactility enhances the degree of information, cited as a major benefit of 3D printing.[19] From our early experience with 3D modeling of the DIEP system, anomalous intramuscular vascular patterns can be clearly realized and muscle cuts better executed to preserve muscle volume while avoiding the intercostal neurovascular bundles. Additional time saving can be potentially enjoyed without expert CT interpretation or tedious vessel exploration (see **video, Supplemental Digital Content 1**, which displays the planning, creation, and use of the 3D printed model. This video is available in the "Related Videos" section of the Full-Text article on PRSGlobalOpen.com or available at ***http://links.lww.com/PRSGO/B45***).



Video Graphic 1. See video, Supplemental Digital Content 1, which displays the planning, creation, and use of the 3D-printed model. This video is available in the "Related Videos" section of the Full-Text article on PRSGlobalOpen.com or available at ***http://links.lww.com/PRSGO/B45***.

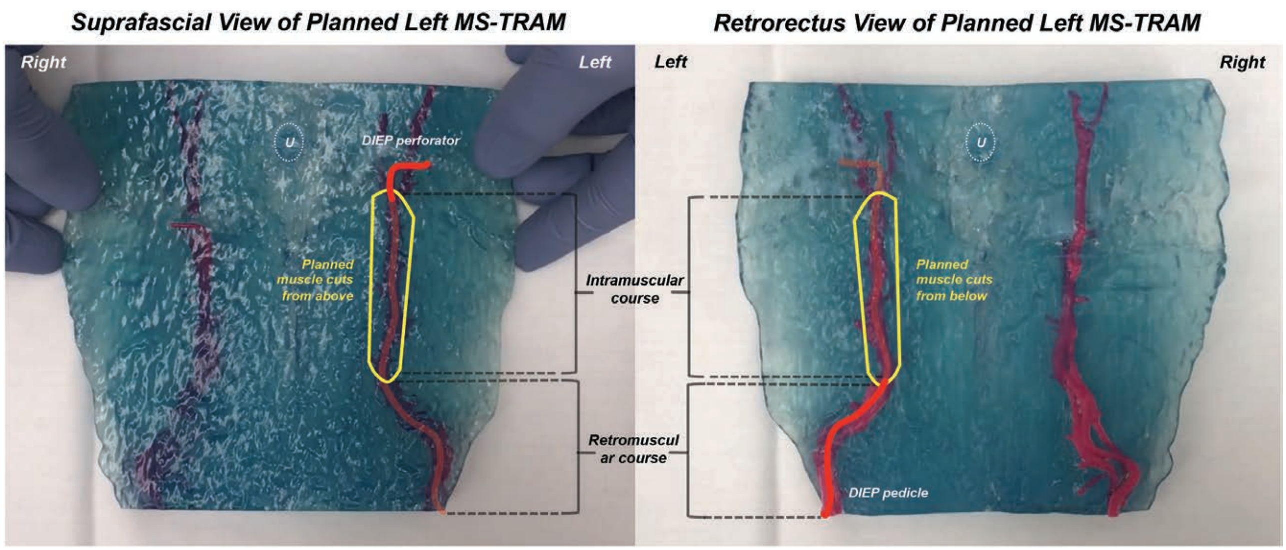


Fig. 2. The 3D-model [printed via the Stratasys (Eden Prairie, Minn.) Connex J735, using Polyjet technology]. A patient with recurrent right breast cancer is to undergo a right skin sparing mastectomy and immediate reconstruction with an abdominal-based free flap from the contralateral hemiabdomen. A 3D-printed model was created. A single perforator off a type 1 system was identified on the left, allowing clear definition for planned intraoperative muscle-sparing cuts around the long intramuscular course.

The authors anticipate the greatest impact of this technology will be for the novice microsurgeon in training.[21–24] Three-dimensional printed templates of the DIEP system have been recently described to trace-out the vessel course atop the abdominal skin to augment flap design.[20] Mehta et al[25] from London have created a remarkable 3D-printed standalone model of bilateral DIEA vasculature through the rectus sheath, used for educating resident surgeons. For improved intraoperative handling, we have applied design modifications to allow sterile wrapping of our model to permit use in the operating room and on the operating field. The current patient-specific 3D-printed DIEP models can be an excellent adjunct to real-time intraoperative training. With models clearly outlining the intramuscular course, residents and fellows can be confidently guided through a safe flap dissection.

The major limitation to this paradigm is cost. Dependent on the institution, these include the CTA, proof planning, and materials printing of the model in conjunction with an outside or institutional entity. As 3D printing capabilities become more widely available, decreased costs and time for models to be produced can be anticipated. Current ongoing studies at our institution are due to evaluate whether the time saved in the operating room from use of our 3D-models could offset the cost of production. In today's technological landscape, the authors present an accurate, intuitive device for deep inferior epigastric vessel visualization.

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