Suture Packaging as a Marker for Intraoperative Image Alignment in Augmented Reality on Mobile Devices

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Summary: Preoperative vascular imaging has become standard practice in the planning of microsurgical breast reconstruction. Currently, translating perforator locations from radiological findings to a patient's abdomen is often not easy or intuitive. Techniques using three-dimensional printing or patient-specific guides have been introduced to superimpose anatomy onto the abdomen for reference. Augmented and mixed reality is currently actively investigated for perforator mapping by superimposing virtual models directly onto the patient. Most techniques have found only limited adoption due to complexity and price. Additionally, a critical step is aligning virtual models to patients. We propose repurposing suture packaging as an image tracking marker. Tracking markers allow quick and easy alignment of virtual models to the individual patient's anatomy. Current techniques are often complicated or expensive and limit intraoperative use of augmented reality models. Suture packs are sterile, readily available, and can be used to align abdominal models on the patients. Using an iPad, the augmented reality models automatically align in the correct position by using a suture pack as a tracking marker. Given the ubiquity of iPads, the combination of these devices with readily available suture packs will predictably lower the barrier to entry and utilization of this technology. Here, our workflow is presented along with its intraoperative utilization. Additionally, we investigated the accuracy of this technology. *(Plast Reconstr Surg Glob Open 2024; 12:e5933; doi: 10.1097/GOX.0000000000005933; Published online 25 June 2024.)*

STREAMLINING INTRAOPERATIVE AR-ADOPTION BY REPURPOSING SUTURE PACKS

Microsurgical breast reconstruction with free abdominal flaps is considered the gold standard. The complexity of deep inferior epigastric artery (DIEA) perforator flaps, however, is related to its variable perforator anatomy.[1] Hence, preoperative vascular imaging is increasingly obtained for preoperative planning. Computed tomography angiography (CTA) has been the predominant perforator imaging modality, with its advantages being fast acquisition times and high arterial detail.[2] However, challenges are related to how to correlate the two-dimensional radiological images with intraoperative anatomy and how to map out perforators easily.

Several approaches have been proposed for perforator mapping, from tracing perforators in two dimensions on transparent films or creating three-dimensional (3D)–printed harvest guides to using virtual 3D models with projectors and mixed reality to superimpose anatomy directly onto patients.[3–5]

Challenges with superimposed virtual 3D models are their accuracy and time to align the models onto the patient. Various techniques have been proposed in other

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surgical fields, including visual alignment based on anatomical landmarks and image tracking markers (eg, QR codes).[6,7] Virtual models are arranged with regard to a virtual marker; the virtual model is then displayed in augmented reality (AR), corresponding to the location of the physical equivalent of the marker.

This technique is currently limited for intraoperative use because one needs a sterile tracking marker. Thus, it does not allow easy, standardized marker orientation on the abdomen. QR codes etched into sterilizable, steel tools have been proposed[5] as well as 3D-printed QR code markers[8]; both are expensive to fabricate and sterilize, thereby limiting intraoperative adoption of AR models.

We propose repurposing an object currently considered waste (ie, suture packaging). Suture packaging is already sterile and has labels printed onto it, providing enough visual structure for it to be used as an alternative image marker. Furthermore, some suture packs already feature small QR codes to help with tracking. Alternatively, other sterile supplies like sterility indicators might be used instead.

Institutional review board approval was obtained before conducting this study. We created virtual abdominal models segmenting the skin, rectus abdominis muscle and DIEA vascular tree from CTA by using a standard threshold-segmentation workflow as previously used for 3D-printing.[9] Skin is colored in translucent gray, muscle in translucent blue, and arteries in opaque red. We arrange the bundled anatomy model together with an image of the suture pack in a 3D-scene in RealityComposer (Apple Computer, Cupertino, Calif.). The suture pack image is forming a virtual ground-plane relative to which we position the model. The 3D-scene can be opened and registered to the suture pack on the abdomen directly from within RealityComposer on an iPad/iPhone or shared as a Reality-file with other surgeons.

Common suture packaging has an opening in the circle center of its rounded sides: we align the model so that the umbilicus on the virtual skin is centered underneath this opening. (**See figure, Supplemental Digital Content 1,** which displays alignment of the virtual 3D abdominal model relative to the suture pack: import, rough alignment of umbilicus and suture pack opening, correct depth placement, and skin removal. The model's umbilicus is placed directly under the opening in the suture pack. When using AR, once the suture pack is positioned above the real umbilicus, the AR model accurately self-aligns. **http://links.lww.com/PRSGO/D315**.) This allows us to standardize intraoperative alignment by simply placing the suture pack vertically on the midline (drawn preoperatively by the surgeon) and aligning the opening with the center of the umbilicus, thus creating a virtual-physical ground-plane at the same level.

Using an iPad (Apple iPad Pro 11-inch, 2021 model, Apple Computer, Calif.), we overlaid the model onto a patient's abdomen, where it automatically aligns into place as previously aligned in the virtual scene. For simplicity, we only display the muscle and DIEA vascular tree. Through previous alignment, the muscle is displayed at the correct depth because the suture pack is the most anterior point in the 3D-scene and in vivo.

Takeaways

Question: Aligning an anatomic augmented reality (AR) model using image markers is a validated technique, eg., using special QR-like codes. Suture packaging has enough detail for tracking and is readily available. We investigated its utility as an intraoperative marker for aligning 3D abdominal anatomy onto a patient.

Findings: In two DIEP-flap cases, we registered an AR model to a patient's abdomen using standard software on an iPad by aligning suture packaging centered on the umbilicus.

Meaning: Suture packaging can be easily repurposed as an intraoperative AR marker alleviating the need for dedicated sterile markers. Further research into streamlining the workflow and accuracy evaluations should follow.

Once the suture pack is placed, the model stays locked in place on the abdomen and the surgeon can move the iPad around to explore the perforator anatomy that is superimposed on the patient. This allows the surgeon to easily trace the vascular tree of the AR model with a marker. Enabled by the sterility of suture packs, the iPad could now be used intraoperatively using a sterile, Food & Drug Administration-approved cover (eShield, Whitney Medical Solutions, Niles, Ill.). Alternatively, it could be used before prepping and draping the patient as in our case.

Figure 1 demonstrates the intraoperative AR alignment of the AR model in two cases. The interactive process of AR model alignment and inspection is demonstrated in Video 1. [**See Video 1 (online),** which displays the operating room. Once the AR visualization is started, the AR model automatically aligns to the suture pack tracker. The now in situ model remains stationary and can be inspected from all sides by moving the iPad in space].

Additionally, we investigated the iPad's general tracking accuracy using QR codes (40 mm × 40 mm) and suture packs. For this, we printed a dot-grid (10-mm spacing) where every dot is the center of a circle with a 5-mm diameter, and the QR-code or suture pack is located in the middle. Virtual scenes for both setups were created where fine-tip cones were aligned, touching the ground-plane from underneath (in analogy to the umbilicus touching the ground-plane from underneath). This allowed easy visual confirmation: if the cone-tips appeared within the circle at any given distance, the tracking was accurate within ±2.5 mm at this distance. We assessed distances up to 10 cm from the origin in all directions, representing perforators at increasing distances from the umbilicus. Most cone-tips (tested on different prints, at different angles, in different conditions) were accurately tracked within ±2.5 mm for QR codes and suture packs, yielding equivalent tracking accuracy overall.

DISCUSSION

We introduced a new, simple, and quick technique for standardized intraoperative image alignment in AR using suture packs. AR and mixed reality are actively investigated for perforator mapping in plastic surgery, but with limited adoption due to complexity and cost of headsets

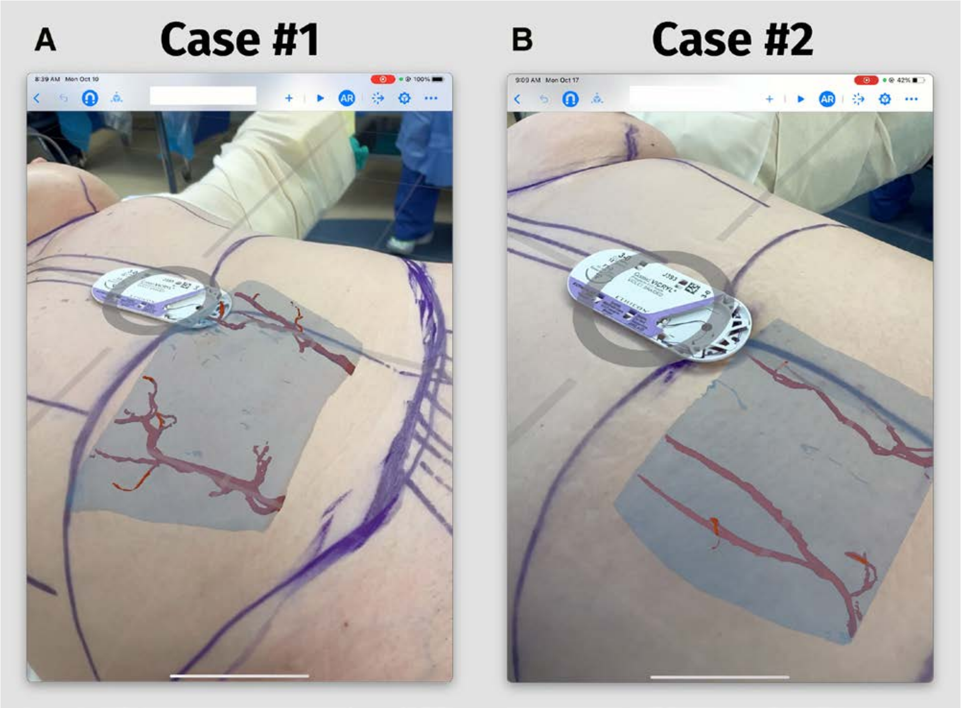

Fig. 1. Demonstration of two intraoperative cases. A, Anterior-posterior view of AR model aligned to suture pack placed above the umbilicus. B, Tracking in space when moved right caudally. Muscle is displayed at accurate depth (as extracted from CTA). Of note, only parts of the rectus muscle and DIEA are modeled and displayed.

or software. We believe having AR models that superimpose vascular anatomy directly onto patients are tremendously helpful. Using devices already owned by most surgeons and trainees, namely smartphones and tablets, is believed to lower the barrier to entry to a minimum. Plastic surgeons wanting to adopt this technique do not need additional equipment, and the increased labor for radiological technologists in creating the models is minimal. The technique can be easily adapted for overlaying not just perforator anatomy, but any anatomy that can be segmented on computed tomography (eg, defect size on donor harvest sites for flap size estimation).

We repurpose something currently considered waste (ie, suture packs). These are sterile, easy to handle and available everywhere, making them a cost-effective alternative intraoperative image tracker. Our technique offers surgeons an intuitive method to incorporate AR into their intraoperative workflow with ease.

Further research into the accuracy of sizing, positioning, and tracking of AR models is needed. We hope to stimulate research on this topic for increased adoption of AR in plastic surgery as a valuable tool to explore patient-specific anatomy for planning and education alike.

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DISCLOSURES

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