INTRODUCTION

The robotic DIEP flap minimizes abdominal donor site morbidity while maximizing pedicle length. Briefly, the procedure includes suprafascial flap elevation, perforator dissection to the posterior rectus sheath though a limited anterior fasciectomy, port access, and robot-assisted intraabdominal pedicle dissection. The fascial incision is limited to only the exposure necessary to perform intramuscular dissection and is usually as short as 1–3 cm. This dramatically improves morbidity compared with the 8–13 cm fascial incision and muscle division required of the traditional open DIEP flap harvest technique.6–4

In our practice, preoperative CT pelvic angiogram (CTA) of the lower abdomen is obtained for most patients being evaluated for DIEP flap breast reconstruction. If CTA shows a sizeable perforator with short intramuscular course, the patient is offered robotic DIEP flap reconstruction. The potential benefit (where benefit is defined as reduction in length of the fascial incision) is the length of the vessel’s intramuscular course (A) subtracted from the entire length of the vessel from perforator to origin at the external iliacs (C). The intramuscular course serves as an approximation for a robotic fascial incision, and the entire length from perforator to external iliacs serves as an approximation for a traditional open fascial incision length. Thus, B (benefit) = C − A.

As institutions consider initiating robotic DIEP programs, it is important to understand the percentage of
patients who may be good candidates for robotic surgery. In this radiographic study, we determine the percent of patients who are candidates for robotic DIEP flap reconstruction and calculate the theoretical benefit of fascial incision spared using this technique versus the open approach. The predicted robotic fascial incision length was also compared with the actual fascial incision length in patients who underwent robotic DIEP flap harvest.

PATIENTS AND METHODS

Institutional review board approval was obtained. CPT codes 19364, 19368, 19369, and S2068 were used to query an institutional electronic medical record retrospectively to identify all consecutive patients who underwent autologous free flap breast reconstruction between 2017 and 2021 by select plastic surgeons. Patients who underwent open or robotic approaches were identified. Patients without preoperative imaging or without dedicated CTA for DIEP flap harvest were excluded.

For each patient, the CTA images and radiologist report were obtained. CT pelvic angiogram scans were performed only at MD Anderson according to the institutional standard of care on the first available scanner within our scanner fleet. This fleet consists of 26 Siemens and GE diagnostic CT scanners. The standardized CTA pelvic imaging protocol consists of a smart prep at the femoral artery region. The images are then acquired in a caudal to cranial direction from symphysis pubis to approximately 5 cm above the umbilicus. Acquisition parameters varied slightly between scanners, but the master protocol was as follows: 120 kVp; Auto mA (dose modulated); 0.5 s rotation time; a pitch of 0.984:1; 2.5 mm slice thickness. The total cephalo-caudal length from peritoneum to pubis at 20 mm and 50 mm thickness, and multiplanar reformatting. Postprocessing maximum intensity projection (MIP) was reconstructed with soft-tissue kernel at 2.5-mm thickness and spacing for standard radiographic review and at 0.625-mm thickness and spacing for subsequent reformatting.

Radiological interpretation of the examination was performed by a group of radiologists, with agreement on standardized reporting format. The branching pattern of DIEAs was determined from the coronal MIPS images. The location of the DIEA perforators exiting the rectus fascia relative to the base of the umbilical stalk was given for only the dominant or enhancing perforators at or below the umbilicus. The size of the perforator of interest was subjectively evaluated, and categorized as large or dominant vessel, medium or moderate size, and small. This practice methodology was adapted due to the limitation of current CT technology in accurately acquiring absolute measurements at the submillimeter level. The limiting z-axis resolution is based on the smallest detector size (0.6 mm) that is currently on commercially available CT scanners. Although this is theoretically the smallest size, the actual size based on the slice sensitivity can be 40%-50% larger according to manufacturer specification.

Furthermore, making such a small measurement by hand further propagates the error significantly. For the purposes of this article, a large size or dominant perforator bundle is usually approximately 3 mm or larger, medium or moderate size 1-2 mm, and small size 1 mm or smaller.

The CTA images and radiologist report were reviewed by a microsurgery fellow. The largest perforator at or below the level of the umbilicus was selected per hemiabdomen as the predicted robotic perforator. If multiple perforators were identified of the same size, the perforator of the shortest intramuscular distance was selected as the predicted robotic perforator. If no perforators or only small perforators were identified, the patient was not considered a candidate for robotic DIEP.

Using the CTA sagittal and axial MIPS series, the cephalo-caudal distance of the intramuscular course (A) was measured and considered the “predicted robotic fascial incision length.” The total cephalo-caudal length from perforator to external iliac (C) was measured and considered the “predicted open fascial incision length.” Robotic fascial incision benefit (B) was calculated as B = C − A (Fig. 1).

The arcuate line was measured to be located at one-third the distance from umbilicus to pubis on sagittal view.5–7 The coordinate of the selected perforator and cephalo-caudal intramuscular course distance were used to determine if the lowest extent of predicted robotic fascial incision would cross or not cross the arcuate line. The incidence of patients with predicted fascial incision on CTA that would not cross the arcuate line was calculated. The rationale for this is that fascial incisions below the arcuate line violate all of the structural components of the abdominal wall at this level, increasing the potential for incisional morbidity.

Operative reports were reviewed to identify robotic versus open approach, actual fascial incision length, and number of perforators harvested. Descriptive statistics were performed. Student t-test was used for normally distributed data, and Mann-Whitney U and Wilcoxon signed-rank test were used for data not normally distributed.

RESULTS

Sixty-two patients were included in the study. Forty-nine patients (98 hemiabdomens) remained after exclusion of...
of eight patients who had no imaging or nondedicated imaging, and five who were not primary patients of the select plastic surgeons. Patient demographics are included in Table 1.

Mean umbilicus to pubis distance was 17.7 cm (SD 1.9 range, 13.3–22.6) with arcuate line located mean of 5.9 cm (SD 0.6; range, 4.4–7.5) below the umbilicus. The predicted robotic fascial incision would avoid crossing the arcuate line in 71% of hemiabdomens. These patients were therefore considered possible candidates for robotic harvest. For 18 hemiabdomens (18%) in 13 patients, no sizeable/dominant perforators were identified on CTA. Although these patients were not considered candidates for robotic flap harvest, they still underwent successful traditional DIEP flap harvest with multiperforator based flaps.

Mean intramuscular perforator distance (A) was 3.1 cm (SD, 2.0; range, 0.0–8.8). Mean total distance from perforator to external iliac vessels (C) was 12.2 cm (SD, 2.3 cm; range, 5.2–17.8). Mean predicted fascial incision benefit (B) was 9.1 cm (P < 0.001; SD, 2.5; range, 4.1–16.9). (See figure, Supplemental Digital Content 1, which displays the box plot of predicted facial incision length by robotic versus open approach. http://links.lww.com/PRSGO/B856.) Operative dictations did not report fascial incision length for the open approach. Fascial incision length was reported for seven robotically harvested flaps in six patients. Median robotic fascial incision length was 3.5 cm (SD, 1.5; range, 3.0–7.0). Predicted fascial incision length on CTA was noted to be a mean of 0.9 cm shorter than the actual incision length (P = 0.374; SD, 2.36; range: −3.5 cm to 3.6 cm). Robotically harvested DIEP flaps included fewer perforators than traditional open DIEP flaps (1.8 versus 2.6, P = 0.058). Among the 49 consecutive patients to undergo DIEP flap breast reconstruction, 13 (27%) underwent robotic DIEP flap harvest.

### DISCUSSION

Part of the groundwork for disseminating the robotic DIEP flap harvest technique is for surgeons to understand which patients are candidates for the robotic approach and the extent of benefit. Additionally, it is helpful for institutional planning to understand how commonly these patients are encountered. Here we present the first study of preoperative imaging to guide robotic DIEP harvest patient selection and report actual and potential incidence of patients with anatomy amenable to robotic DIEP flap harvest. We further delineate the general indications for robotic DIEP harvest. Namely, the identification of at least one sizeable/dominant perforator with an intramuscular course that joins the submuscular pedicle above the level of the arcuate line.

Abdominal morbidity is an important consideration in DIEP flap harvest and breast reconstruction. Our findings reveal a mean 9.1 cm fascial incision benefit with robotic DIEP and potential to avoid crossing the arcuate line in 71% of hemiabdomens. The exact fascial incision length spared to justify robotic DIEP harvest is unknown and will be elucidated with further outcomes and cost utility studies. However, our group and others believe any violation of the anterior rectus sheath below the arcuate line places patients at particular risk of bulge and hernia. Our estimation of perforator intramuscular distance on CTA is longer than that previously reported in a cadaveric study. The three 5- to 8-mm port site incisions were not included in the total fascial incision length in the robotic cohort. This was felt to be functionally irrelevant, as the incidence of robotic port-site hernia is exceedingly small and many robotic surgeons do not routinely close the port-site fascial incisions lateral to the linea alba. Damani et al recently reported a robotic port-site hernia rate of 0.032% in 34,698 8 mm port sites without fascial closure. Despite this, it is our practice to routinely close the three port sites with figure of eight fascial sutures and we have not had any port-site morbidity.

Other techniques have been described for minimally invasive DIEP flap harvest using laparoscopic-assistance and endoscopic assistance. Additionally, robotic or laparoscopic-assisted DIEP harvest could be performed by total

| Variable                  | Value     |
|---------------------------|-----------|
| Mean age ± SD, y          | 50.0 ± 9.9 |
| Mean BMI ± SD, kg/m²      | 30.8 ± 4.2 |
| Mean height, cm           | 161.9 ± 6.4 |
| Race                      |           |
| White                     | 69.4%     |
| Black or African American | 12.9%     |
| Asian                     | 32.3%     |
| American Indian or Alaska Native | 1.6% |
| Other                     | 13.6%     |
extraperitoneal approach rather than by our preferred transabdominal pre-peritoneal (TAPP) approach.10,11 Our rationale for performing a minimally invasive DIEP using the TAPP approach has been previously described.12 Briefly, robotic instrumentation allows for considerably finer small vessel dissection due to scaled, wristed motion and tremor elimination, and the intraperitoneal approach allows the deep inferior epigastric vessels to be dissected from the side rather than along its foreshortened, long axis. The disadvantage of our approach is entrance into the peritoneal cavity, although all the work is performed along the anterior abdominal wall and has been without adverse event in over 20 cases. Regardless of the device or minimally-invasive approach used, the fascial incision length should be similar, as found in a cadaveric model of total extraperitoneal approach versus TAPP DIEP harvest.13 Similar preoperative imaging principles would apply whether DIEP harvest is performed by total extraperitoneal approach or TAPP approach. Delay procedure has been described to isolate a low perforator.14 However, this may not be feasible in immediate reconstruction, and a tradeoff occurs between the cosmetic appeal of the low abdominal incision and the increased morbidity of a low fascial incision beyond the arcuate line, as can often be avoided with robotic TAPP DIEP harvest. Additionally, compromising dominant perforators for the convenience of lower, smaller perforators seems counter to basic microsurgical principles.

Others have proposed using the robot for perforator dissection, which could broaden the indications for robotic DIEP to include patients with a longer intramuscular course.15 However, we believe the robotic instruments currently available are inefficient for perforator dissection.

We report an actual incidence of 27% robotic DIEP harvest despite preoperative CTA suggesting favorable anatomy far more frequently. Other barriers to robotic DIEP harvest exist beyond anatomic unfavorability, including robot availability and surgeon comfort with the robot. Additionally, during execution of robotic DIEP harvest, the surgeon may encounter intraoperative anatomy, leading to the use of a perforator (or perforators) different than predicted by imaging. Safe flap harvest that includes the most appropriate perforators based on caliber, location, and flow is always prioritized. This may necessitate creating a larger fascial incision or proceeding with open harvest. On the other hand, if indications are expanded to include longer fascial incisions that simply stop cephalad to the arcuate line, the percent of patients considered can be increased without adverse event in over 20 cases. Regardless of the device or minimally-invasive approach used, the fascial incision length should be similar, as found in a cadaveric model of total extraperitoneal approach versus TAPP DIEP harvest.13 Similar preoperative imaging principles would apply whether DIEP harvest is performed by total extraperitoneal approach or TAPP approach. Delay procedure has been described to isolate a low perforator.14 However, this may not be feasible in immediate reconstruction, and a tradeoff occurs between the cosmetic appeal of the low abdominal incision and the increased morbidity of a low fascial incision beyond the arcuate line, as can often be avoided with robotic TAPP DIEP harvest. Additionally, compromising dominant perforators for the convenience of lower, smaller perforators seems counter to basic microsurgical principles.

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This study is limited by its retrospective design. The small number of patients with intraoperative details limited more sophisticated analyses and a higher-powered validation of the measurements. Larger, prospective, and randomized studies that include harvest time, fascial lengths, and clinical end points will be required to define the clinical benefits of robotic DIEP flap harvest.

CONCLUSION

Using abdominal CTA, we find that a majority of patients would benefit from robotic DIEP harvest with short fascial incisions that do not cross the arcuate line.

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