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Learning Curve Analysis for Robotic-assisted Harvest of Deep Inferior Epigastric Perforator Flap

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Summary: The deep inferior epigastric perforator (DIEP) flap is the preferred method for autologous breast reconstruction after mastectomy, but risks the development of hernia, bulge, and decreased core strength. Robotic harvest of DIEP vessels may limit abdominal wall morbidity through smaller fascial incisions and preservation of motor nerves. This study shows the expected learning curve (LC) for robotic harvest and compares the LC between a general surgeon (GS) and a plastic surgeon (PS). A retrospective cohort study was performed for patients who underwent bilateral robotic DIEP flap harvest from October 2021 to September 2022. We evaluated robotic pedicle dissection time (DT) and compared the times between GS and PS. We calculated LC for each surgeon using the cumulative sum (CUSUM) method, $\text{CUSUM} = \sum_{i=1}^{n}\left(xi - \underset{-}{\mu}\right)$. The LC was identified as the peak of the CUSUM graph. Forty-four flap dissections were recorded during the collection period: 27 by the PS and 17 by the GS. There was no significant difference in DT between the GS and the PS ($P = 0.366$), and both surgeons saw a decrease in DT over time. Using the CUSUM method, we see the peak of the plot at patient 9 for the PS and the peak of the plot at patient 5 for the GS, after which cumulative DT decreased. As robotic harvest of DIEP flaps becomes accepted, plastic surgeons who wish to incorporate it into their practice may achieve proficiency in their DT within 10 flap harvests and a similar DT compared with robotic-trained GSs. *(Plast Reconstr Surg Glob Open 2024; 12:e6242; doi: 10.1097/GOX.0000000000006242; Published online 11 October 2024.)*

INTRODUCTION

Minimally invasive surgery is the gold standard in many surgical fields and is extending to plastic and reconstructive surgery. The deep inferior epigastric perforator (DIEP) flap is the preferred method for autologous breast reconstruction following mastectomy, although it risks the development of hernia, bulge, and decreased core strength.[1] In response, robotic-assisted surgery (RAS) is being incorporated, and the technique for robotic-assisted trans-abdominal preperitoneal (TAPP) harvest of DIEP vessels limits abdominal wall morbidity through smaller fascial incisions and preservation of motor nerves when compared with standard DIEP.[2,3]

DIEP flap reconstruction is a demanding operation, and surgeons with limited robotic experience may be hesitant to attempt robotic harvest. The TAPP technique leverages advantages of the da Vinci Robotic Surgical System (Intuitive Surgical, Inc., Sunnyvale, Calif.), including three-dimensional visualization with 15× magnification, tremor elimination, and 540-degree instrument articulation.[4]

Other surgical fields incorporate RAS into complex cases such as pancreaticoduodenectomy and have shown that a learning curve (LC) could be safely achieved at high-volume centers.[4] This study shows the expected LC for surgeons interested in incorporating the TAPP technique into their practice and compares the LC between a general surgeon (GS) and a plastic surgeon (PS).

METHODS

Robotic harvest of DIEP flaps for breast reconstruction was first performed at our institution in October 2021

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and has been performed by either a GS (W.N.) or a PS (D.M.). In some instances, each surgeon performed a side on the same patient. The GS is da Vinci robot certified and had performed hundreds of TAPP procedures before this study. The PS is a reconstructive microsurgeon who underwent an independent pathway for training. He had some exposure to robotics during his final 2 years of training followed by 7 years without use of robotics in training/practice. Before this study, he had performed 10 cases using the da Vinci robots (Si, Xi, SP): robotic VRAM/rectus harvest, free flap inset for head and neck reconstruction, and latissimus dorsi harvest for breast.

Robotic Technique

Briefly, following exposure of recipient chest vessels and suprafascial dissection of DIE perforators, the abdomen is insufflated, and three robotic ports target the pelvis.[5] (**See figure, Supplemental Digital Content 1**, which displays three 8-mm ports placed to triangulate to the pelvis. Use of bariatric ports is recommended, especially if the patient has a short torso or a high perforator. **http://links.lww.com/PRSGO/D563**.)

The peritoneum overlying the DIE vessels is opened and dissection is commenced with use of indocyanine green dye, as needed.[6] Once the intracorporeal dissection meets the suprafascial dissection, the base of the DIE vessels is divided and externalized. [**See figure, Supplemental Digital Content 2**, which displays the pedicle dissection; the pedicle may be either clipped (two Hem-o-lok clips at the origin and one on the pedicle side) or coagulated with vessel sealer and retrieved. Our current approach is clipping the origin and then cutting using the vessel sealer with the caveat of vessel trimming 3–5 mm during the microsurgical anastomosis. It is not only faster by avoiding multiple instrument passes, but pedicle length is saved as the clips are bulky. **http://links.lww.com/PRSGO/D564**.] The peritoneum is closed, and the robot is undocked.

Study Variables

A retrospective review was performed for patients who underwent bilateral robotic DIEP flap harvest from October 2021 to September 2022. Patient characteristics of age, body mass index, and previous abdominal surgery were collected. Robotic pedicle dissection time (DT) was determined from operative records. Complications such as pedicle injury, intraabdominal injury, and postoperative flap complications were noted as well.

Statistical Analysis

The LC was statistically calculated using the cumulative sum (CUSUM) method as the recommended gold standard.[7] The CUSUM is the summation of differences between DT for each patient and the mean DT for all patients, $\text{CUSUM} = \sum_{i=1}^{n}\left(xi - \bar{\mu}\right)$. The LC was identified as the peak of the CUSUM graph.

Patients were then divided into two groups: before achieving the LC and after achieving the LC. The previously listed variables were compared between pre- and post-LC patients using Mann-Whitney U or Fisher exact test for continuous and categorical variables. A P value less than 0.05 was considered statistically significant. These analyses were performed separately for the PS and GS. Statistical analysis comparing the groups was carried out using Stata version 16.1. This retrospective study received institutional review board approval (2023-080).

Takeaways

Question: How long does it take to become proficient in elevating the deep inferior epigastric perforator (DIEP) pedicle using a robot?

Findings: Twenty-seven pedicle harvests performed by a plastic surgeon were compared with 17 harvests by a robotic hernia general surgeon for dissection times and learning curve (cumulative sum method). Although the plastic surgeon became proficient after nine cases and the general surgeon after five cases, the dissection time was not statistically significant with a postlearning curve dissection time of 32 and 27.3 minutes, respectively.

Meaning: Surgeons interested in adopting the robot assisted DIEP pedicle can expect to become proficient within 10 harvests.

RESULTS

During the collection period, 44 flap dissections were performed: 27 by the PS and 17 by the GS. There was no significant difference in DT between the GS (34.8 minutes) and PS (44.6 minutes) ($P = 0.366$). Both surgeons saw a decrease in DT over time (Fig. 1). CUSUM showed the peak of the graph at patient 9 for the PS and the peak of the graph at patient 5 for the GS, after which DT consistently decreased (Figs. 2, 3). In seven patients, each surgeon performed one side, but this sample was too small for subset analysis.

For both surgeons, there was no difference in patient characteristics pre- and post-LC. For both, there was significantly decreased DT (52.8–27.3 minutes for GS, $P = 0.003$ and 69.7–32 minutes for PS, $P = 0.001$) (Table 1). Post-LC, there was no difference in DT between the surgeons ($P = 0.319$). There were no immediate (intraabdominal injuries, pedicle injuries, conversion to open, flap losses) or long-term (hernia or bulge at 1 year) postoperative complications from use of the robot in any of the cases.

DISCUSSION

Autologous breast reconstruction has made enormous strides in decreasing donor site morbidity, including with the incorporation of RAS for DIEP harvest. Compared with traditional laparoscopy, RAS has a reduced LC.[4,8] Given the natural movements translated through robotic arms, skillsets possessed by microsurgeons are easily transferred to RAS, as demonstrated by quick improvement in robotic microvascular anastomoses.[9] Muller et al[7] performed a systematic review for robotic pancreaticoduodenectomy and discussed three phases of LC to achieve competency, proficiency, and mastery. We have shown achievement of all three phases

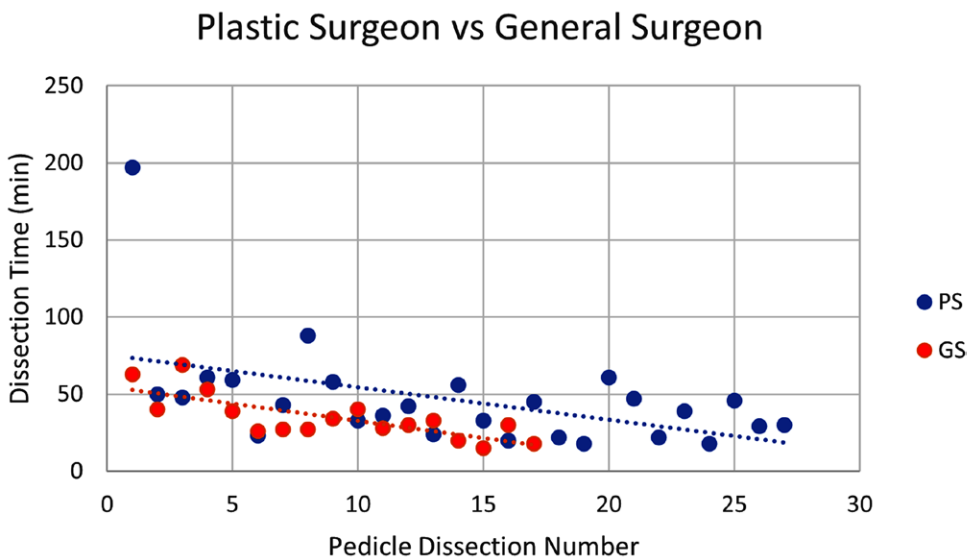

Fig. 1. Comparison of DTs between PS and GS.

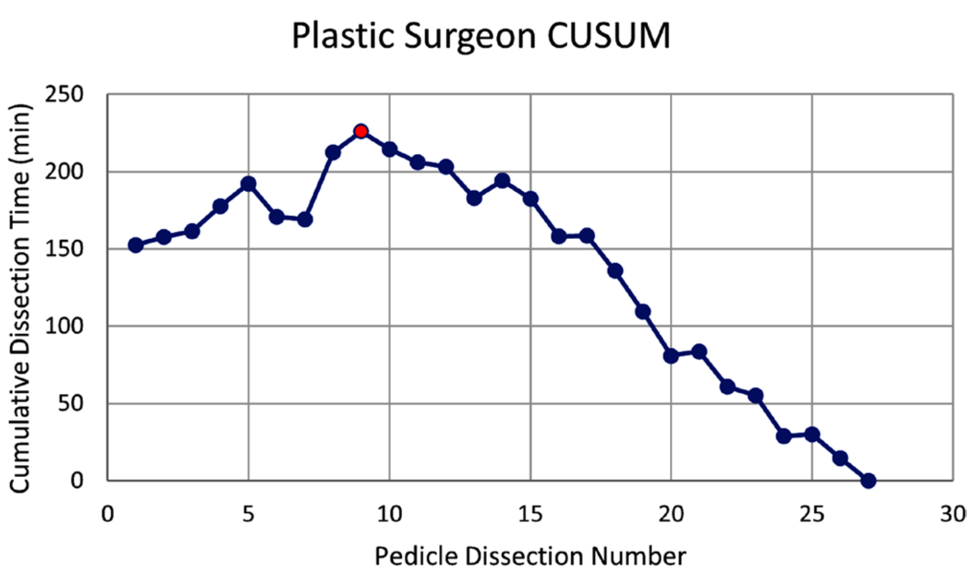

Fig. 2. LC for PS. Pedicle DTs consistently decreased after the ninth dissection.

of the LC as evidenced by similar operative time compared with standard DIEPs, similar pedicle lengths, similar vessel sizes, smaller fascial incisions, and no pedicle complications in our cohort.[3]

The CUSUM was introduced in the manufacturing industry in 1954, adopted in the medical field in the 1970s, and is now the preferred means of defining an LC.[7] It demonstrates deviation from the mean on a case-by-case basis and graphically depicts changes in variables. We show that a PS can achieve the LC for robotic dissection within 10 cases. Although the PS did train under the independent pathway and had some limited robotic experience, as mentioned previously, this is minimal compared with the GS who has performed hundreds of robotic TAPP procedures as well as thousands of conventional laparoscopies. The comparable LCs despite vastly different prior experiences is encouraging for any microsurgeon wishing to incorporate robotic surgery.

Although initially we chose patients with more favorable perforator anatomy, as defined by computed tomography angiography, we expanded to offer it to all patients interested. We believe that a fast LC in an otherwise novel and delicate procedure can be achieved by a PS. The first dissection by the PS required 197 minutes, an unusually prolonged duration, primarily attributable to unique patient characteristics including a high perforator, long pedicle length, and a dissection which required four instrument changes for each branch divided with clips. As comfort increased, we modified our technique to increase efficiency and rarely use clips or indocyanine green. Without the first DT for the PS, the average time would have been 38.7 minutes (versus 44.6). As more PSs

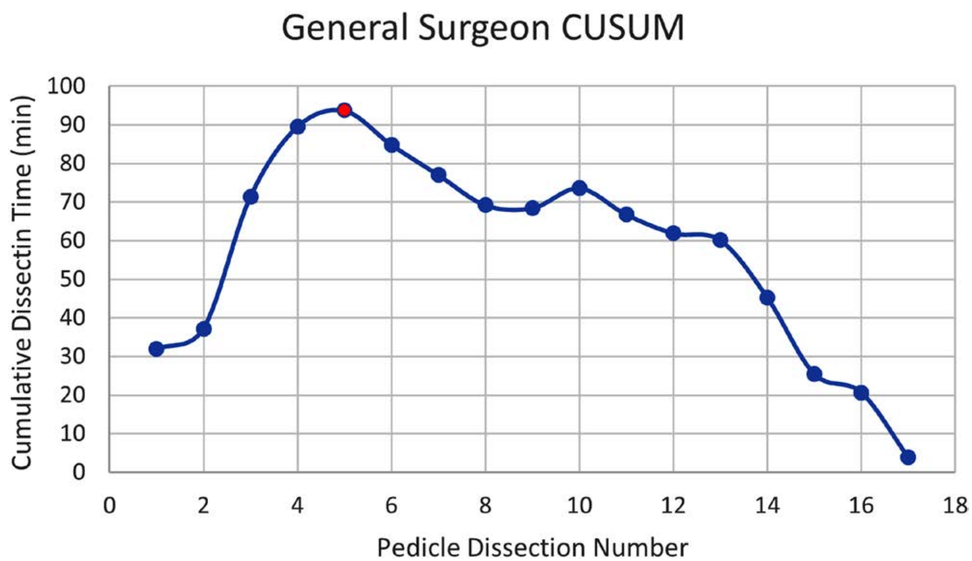

Fig. 3. LC for GS. GS pedicle DTs consistently decreased after the fifth dissection.

Table 1. Patient Characteristics and Pedicle DT Comparison Pre- and Post-LC

	Total	Pre-LC	Post-LC	*P*
Flaps				
PS	27	9	18	
GS	17	5	12	
Age, mean (SD), y				
PS	48.3 (12.3)	50.3 (9.9)	47.2 (13.7)	0.421
GS	47.5 (10.2)	48.3 (9.2)	47.1 (11.3)	0.932
Body mass index, mean (SD)				
PS	28.8 (6.1)	27.6 (5.0)	29.5 (6.7)	0.513
GS	28.7 (5.2)	29.8 (7.4)	28.2 (4.2)	0.734
Prior abdominal surgery				
PS	13	5	8	0.615
GS	8	2	6	0.547
Pedicle dissection time (SD), min				
PS	44.6 (34.2)	69.7 (50.8)	32 (11.9)	**0.001**
GS	34.8 (14.9)	52.8 (13.4)	27.3 (7)	**0.003**

Values in boldface indicate statistical significance.

embrace the benefits of RAS, we should train the next generation of microsurgeons in the latest techniques which ultimately benefit our patients.[10]

CONCLUSION

Incorporating the robotic-assisted DIEP flap for autologous breast reconstruction has a rapid LC and can be easily assimilated by PSs wishing to adopt a minimally invasive approach to harvest of the flap.

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DISCLOSURES

Dr. Murariu is a consultant for MTF Biologics, Sientra, and HMP Education; Dr. Moreira is a consultant for Axogen. The other authors have no financial interest to declare in relation to the content of this article.

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