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ORIGINAL ARTICLE

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Time-dependent factors in DIEP flap breast reconstruction

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Background: The process of harvesting and performing microsurgical anastomosis may lengthen deep inferior epigastric artery perforator (DIEP) flap breast reconstruction affecting results and patient safety. The aim of the study was to investigate the associations between predictors and operative time (OT).

Methods: Between 2004 and 2016, 336 immediate and 68 delayed unilateral reconstructions were performed in 404 patients. Age, weight, height, body mass index (BMI), nulliparity, or pluriparity condition were collected to determine the impact of patient characteristics on OT. Flap weight, mastectomy type, flap zone, perforator number, venous anastomoses, recipient vessels selection, reconstruction timing, contralateral symmetrization, and a dedicated anesthesiologist were analyzed as possible predictors.

Results: Mean OT was 289 min (range, 150–550 min). Using univariate analysis, for each increment of BMI value and patient weight OT increased, respectively, 3.5- and 1.4 min (97.5% CI: 1.768–5.145, 97.5% CI: 0.739–1.949; $P < 0.001$). Skin-sparing mastectomy (SSM) (97.5% CI: 2.487–36.637; $P = 0.025$), perforator number, and venous anastomoses (97.5% CI: 24.468–43.690, 97.5% CI: 24.843–50.492; $P < 0.001$) negatively influenced OT while nipple-sparing mastectomy (NSM) reduced OT of 22.7-min (97.5% CI: −40.333 to −5.098; $P = 0.012$). The use of circumflex scapular vessels as recipients reduced OT of 75.4-min while internal mammary vessels (IMV) increased OT of 55.8-min (97.5% CI: −88.631 to −62.209, 97.5% CI: 22.918–88.642; $P < 0.001$). A dedicated anesthesiologist and the learning curve (LC) reduced OT, respectively, of 39.63-min and of 13-min for every year (97.5% CI: −57.119 to −22.137, 97.5% CI: −14.666 to −11.898; $P < 0.001$). Using multivariate regression, LC was a negative predictor while SSM, perforators number, superficial epigastric vein, IMV, and flap weight were positive predictors ($P < 0.001$).

Conclusions: The increase of flap weight, related perforators number, and venous drainage negatively influence OT. LC meaning systematic approach for surgery can optimize DIEP flap surgery efficiency.

1 | INTRODUCTION

The deep inferior epigastric artery perforator (DIEP) flap is currently the preferred method for breast reconstruction in a broad spectrum of patients. Its autologous nature and the minimal donor site morbidity together with the similarity between the abdominal and breast's subcutaneous tissue make this flap ideal in terms of shape, consistency, durability, and resistance to adjuvant treatments (Granzow, Levine, Chiu, & Allen, 2006; Laporta, Longo, Sorotos, & Santanelli di Pompeo, in press; Santanelli, Longo, Angelini, Laporta, & Paolini, 2011). Its benefits over implant-based or muscle-based reconstructive options have been already well documented. Despite its popularity, the process of harvesting and performing the microsurgical anastomosis may lengthen the procedure, which could influence results and patient safety (Lee, Lee, Nam, & Mun, 2013; Marre & Hontanilla, 2013). Recent studies have reported a mean operative time (OT) for a unilateral DIEP between 4 and 8 h, and for a bilateral DIEP, an average of 8 to 12 h (Schaverien et al., 2011; Tong, Dixon, Ekis, & Halvorson, 2012).

The vascular variability of perforator vessels has prompted the search for an optimal imaging technique to facilitate surgical planning. Selection of suitable perforators using preoperative imaging has been shown to decrease the OT, to decrease flap-related complications, and donor-site morbidity (Acosta et al., 2010; Casey et al., 2009; Rozen et al., 2008; Smit et al., 2009).

The goal of the current study was to investigate the effect of patient and operation related variables on the OT in DIEP flap breast reconstruction.

2 | PATIENTS AND METHODS

We performed a retrospective chart review of 404 consecutive patients who underwent immediate ($n = 336$) and delayed ($n = 68$) DIEP flap breast reconstruction between 2004 and 2016.

Patients with multiple abdominal scars or inadequate abdominal tissue (nine cases) that could have been candidates for DIEP flap reconstruction as previously reported (Laporta, Longo, Sorotos, Pagnoni, & Santanelli di Pompeo, 2015a; Laporta et al., in press) were not included in the current study to avoid any misdealing data interpretation.

Sixteen patients who underwent bilateral reconstruction were also excluded. Of note, if patient was a potential candidate for postmastectomy radiotherapy, a delayed reconstruction was always preferred at our institution. The senior surgeon carried out all the procedures.

Patient characteristics and reconstructive methods are summarized in Table 1. The mean follow-up postoperatively was 6 months. Medical history (hypothyroidism, diabetes mellitus, history of smoking, hypertension, and hypercholesterolemia), perioperative course, and postoperative complications were collected from each patient to evaluate patient safety and outcomes. Age, weight, height, body mass index (BMI), nulliparity, or pluriparity condition were collected to determine the impact of patient characteristics on duration of surgery. Operative data collection included the following: flap weight, type and number of perforators, type of mastectomy [skin-sparing mastectomy (SSM), nipple-sparing mastectomy (NSM), and radical or modified radical mastectomy (RM or MRM)], side of mastectomy, type of flap [adipose DIEP flap if completely de-epithelialized; island DIEP flap if partially de-epithelialized; cutaneous DIEP flap if not de-epithelialized], flap side, flap zones (zones I–II/zones I–III), number of anastomosed veins, the harvest of the superficial epigastric vein (SEV), type of recipient vessels [thoracodorsal vessels (TDV); circumflex scapular vessels (CSV); internal mammary vessels (IMV)], timing of reconstruction, contralateral symmetrization procedure, and a dedicated anesthesiologist. Total length of procedure from skin incision to closure was recorded looking for the impact of the different variables analyzed on the variable time.

2.1 | Surgical procedure

Preoperative planning consisted of a thorough history and physical examination in order to determine which patients were suitable candidates for DIEP flap breast reconstruction.

TABLE 1 Patient characteristics and reconstructive methods

Patient population	
No. of patients	404
Age (year)	
Mean	51.92
Range	29–78
BMI (kg/m^2)	
Mean	25.21
Range	17.63–42.01
Operative time (min)	
Mean	288.84
Range	150–550
Breast side (number of cases)	
Right	187
Left	217
Mastectomy type (number of cases)	
Radical mastectomy	256
SSM	77
NSM	71
Type of flap (number of flap)	
Cutaneous adipose	256
Island	72
Adipose	76
Flap zones (number of flap)	
Zone I, II, III	384
Zone I, II	20
Flap weight (g)	
Mean	556.75
Range	220–1310
Reconstruction timing (number of cases)	
Immediate	336
Delayed	68
Number of perforators (number of flap)	
1	106
2	240
3	54
4	4
Perforator row (number of cases)	
Medial	180
Lateral	207
Medial/Lateral	17
Number of veins (number of flap)	
1	135
2	263
3	6
Superficial vein Yes/No (number of flap)	279/125
Pedicle Anastomosis (number of flap)	
Thoracodorsal pedicle	103
Circumflex scapular pedicle	249
Internal mammary	52
Dedicated anesthesiologist Yes/No	338/66
Nulliparous patient Yes/No (number of patient)	53/351
Contralateral surgery Yes/No ((number of flap)	44/360

The day before surgery, the patient was marked identifying the abdominal perforators with a portable Doppler. Preoperative markings were done with the patient in upright position. The general surgeon indicated the mastectomy type while the plastic surgeon planned the DIEP flap harvest (Laporta et al., 2016; Laporta, Longo, Sorotos, Pagnoni, & Santanelli di Pompeo, 2015b) and a contralateral breast reduction/mastopexy if needed. Standard abdominoplasty markings were drawn in the sitting or standing position and the flap markings included vascular zones I–III for unilateral reconstructions according to Holm, Mayr, Höfter, and Ninkovic (2006). The side of the abdomen contralateral to the breast to be reconstructed was always preferred.

The day of DIEP flap surgery, a dedicated operating room team, consisting of two trained scrub technicians for microsurgical procedure, a circulating nurse, and two dedicated anesthesiologists, was guaranteed. If immediate reconstruction was scheduled, a separate operating room table with an additional scrub technician was available for the breast surgery team that was usually comprised of two breast surgeons. The staff members assisting during the operation included two plastic surgery residents, one plastic surgery fellow, the senior surgeon, and the assisting surgeon.

The senior surgeon harvested the flap and performed the microsurgical anastomosis, while the assisting surgeon assisted the senior surgeon with the help of the plastic surgery fellow and performed recipient vessel dissection following mastectomy procedure. The plastic surgery residents supported the assisting surgeon during recipient vessels dissection and performed donor site closure.

DIEP flap harvest, mastectomy procedure, and recipient vessels dissection were routinely performed simultaneously. The flap was transferred, rotated 180 degrees, and fixed temporarily to the chest wall; both arterial and venous anastomoses were performed while a second team carried out donor site closure. Next, the senior surgeon completed flap insetting, while the assisting surgeon performed the contralateral breast reduction/mastopexy if already planned.

2.2 | Statistical analysis

Statistical analyses were performed using R version 3.0.2 (R Development Core Team, Vienna, Austria). All the collected variables were considered as possible predictors. Univariate and multivariate linear regression was performed to investigate associations between predictors and the outcome (OT). The outcome was successfully assessed for normality through visual analysis of density estimates and goodness of fit via Kolmogorov–Smirnov test statistics. The final multivariable model was chosen by minimizing the Akaike Information Criterion (AIC) in a forward stepwise fashion. A P value of below .05 was considered as significant.

3 | RESULTS

Patient characteristics and reconstructive methods are summarized in Table 1. Mean age at surgery was 51.92 years (range, 29–78 years) while mean BMI was 25.21 kg/m^2 (range, 17.63–42 kg/m^2). One-hundred and ten were active smokers at the time of reconstruction and 20 suffered hypertension. There were only five diabetic patients. The mean OT was 289 min, range 150–550 min.

All the variables analyzed are reported in Table 2. Using univariate analysis, the learning curve (LC) appeared one of the most importance variable able to reduce the OT of 13 min for every year (97.5% CI: 14.666 to −11.898, $P < 0.001$). Regarding the type of mastectomy, SSM negatively influenced the OT compared to RM/MRM with time increase of 19.57 min on the total procedure while NSM reduced the OT of 22.7 min (97.5% CI: 2.487–36.637, $P = 0.025$). The harvest of an island flap increased the OT of 20 min (97.5% CI: 2.706–37.680, $P = 0.024$) while an adipose DIEP flap could reduce the OT of 20 min (97.5% CI: −37.522 to −3.274, $P = 0.020$). No statistical difference was observed between immediate and delayed reconstruction, even if the last one could increase the procedure of 17.5 min.

For any perforator used to harvest the flap, an increase of 34 min was observed that was statistically significant (97.5% CI: 24.468–43.690, $P < 0.001$). The lateral perforator row or the use of two perforators from both the lateral and medial rows negatively influenced the OT (97.5% CI: 16.905–43.357, $P < 0.001$; 97.5% CI: 6.746–72.602, $P = 0.018$). The number of venous anastomoses also was statistically significant with an increase in time of 37.7 min (97.5% CI: 24.843–50.492, $P < 0.001$). Three types of recipient vessels were used over the time preferring in the last years the CSV. From the data, the use of CSV as recipient vessels reduced the OT of 75.4 min (97.5% CI: −88.631 to −62.209, $P < 0.001$) while the use of IMV increased the OT of 55.8 minute (97.5% CI: 22.918–88.642, $P < 0.001$). BMI and patient weight were two important variables to influence negatively the OT. For each increment of BMI value or patient weight, the OT increased respectively of 3.5- and 1.4 min that was significant (97.5% CI: 1.768–5.145, $P < 0.001$; 97.5% CI: 0.739–1.949, $P < 0.001$). The mean flap weight was 556.75 g (range, 220–1310 g) and did not influence the OT. A dedicated anesthesiologist reduced the total procedure of 39.63 min (97.5% CI: −57.119 to −22.137, $P < 0.001$), while a contralateral symmetrization did not influence the OT ($P = 0.811$).

Using multivariate regression, the LC was a positive predictor to decrease the overall OT of 12.4 min (97.5% CI: −14.373 to −10.491; $P < 0.001$). The SSM, the number of perforators, the use of perforators from both medial/lateral rows, the harvest of the SEV, the use of IMV as recipient vessels, and flap weight were negative predictors ($P < 0.001$). Flap weight influenced negatively the OT (97.5% CI: 0.029–0.076; $P < 0.001$) for each gram of increase (Table 3).

Of the 404 flaps, 16 cases (3.96%) were taken back to theater demonstrating true pedicle compromise. Thirteen flaps presenting a venous impairment (81.25%) were salvaged, while one case of no-reflow phenomenon, one case of arterial thrombosis, and one case of both arterial and venous thrombosis failed. The association between OT and flap failure or take-back was not investigated.

Nine cases of fat necrosis and 32 of partial flap necrosis were observed. Fat necrosis was defined as ischemic tissue loss characterized by subcutaneous firmness of 2–5 cm in diameter while partial flap loss was defined as fat necrosis >5 cm in diameter or tissue loss >10%

TABLE 2 Univariate statistical analysis

Univariate analysis			
Variable	**Estimate**	**97.5% C.I**	***P*-value**
Learning curve	−13.282	−14.666 to −11.898	<0.001
Age	−0.367	−1.062 to 0.328	0.3
Left breast vs. right breast	2.301	−10.982 to 15.584	0.734
Type of mastectomy			
Skin-sparing mastectomy	19.562	2.487–36.637	0.025
Nipple-sparing mastectomy	−22.715	−40.333 to −5.098	0.012
Type of flap			
Adipose flap	−20.398	−37.522 to −3.274	0.020
Island flap	20.193	2.706–37.680	0.024
Delayed reconstruction	17.513	−0.108 to 35.134	0.51
Flap zones	−0.473	−31.010 to 30.064	0.976
Flap side			
Left flap	0.794	−12.510 to 14.097	0.907
Vertical flap	30.051	−103.535 to 163.636	0.659
Flap weight	0.023	−0.010 to 0.055	0.173
Number of flap perforators	34.079	24.468–43.690	<0.001
Perforator row			
Lateral row	30.131	16.905–43.357	<0.001
Medial/lateral row	39.674	6.746–72.602	0.018
Number of veins	37.668	24.843–50.492	<0.001
Superficial epigastric vein	2.359	−11.969 to 16.687	0.746
Recipient anastomosis site (vs. TD)			
Circumflex scapular vessels	−75.420	−88.631 to −62.209	<0.001
Internal mammary vessels	55.780	22.918–88.642	<0.001
Dedicated anesthesiologist	−39.628	−57.119 to 22.137	<0.001
Nulliparous patient	−10.294	−29.888 to 9.301	0.302
Contralateral symmetrization	2.582	−18.680 to 23.843	0.811
BMI	3.457	1.768–5.145	<0.001
Weight	1.344	0.739–1.949	<0.001
Height	0.696	−0.431 to 1.823	0.225

BMI: body mass index; TD: thoracodorsal vessels.

of the flap. The subcutaneous firmness of fat necrosis was removed and the final aesthetic outcome was not injured. In the case of partial flap loss, flap reshaping and/or fat-graft session was carried out to correct volume defect.

4 | DISCUSSION

Autologous breast reconstruction has witnessed tremendous advances over the years. Although alternative donor site options are becoming popularized, the abdomen is still considered by many surgeons to be the best choice for autologous reconstruction. Numerous studies have been published to assess outcomes, focusing on flap and donor-site complications, costs, and patient satisfaction (Bui et al., 2007; Chang et al., 2013, 2016; Fischer et al., 2013; Zhong et al., 2012). Nevertheless, few studies focused on how to optimize the procedure reducing the OT and improve patient outcomes.

The benefits of DIEP flap reconstruction over implant-based or muscle-based reconstructive options have been already well documented. Although it remains the workhorse perforator flap for autologous reconstruction, the disadvantage of a perforator flap is correlated to the tedious identification and dissection of perforator vessels. The main issue is that the DIEP flap cannot be an all-day procedure, thus increasing the surgical stress for the patient and forcing to renounce this type of reconstruction. There are certain factors, such as technical skill and surgeon experience that can significantly influence the OT,

TABLE 3 Multivariate statistical analysis

Multivariate analysis			
Variable	**Estimate**	**97.5% C.I**	***P*-value**
Learning curve	−12.432	−14.373 to −10.491	<0.001
Type of mastectomy			
Skin-sparing mastectomy	20.482	8.768–32.195	<0.001
Nipple-sparing mastectomy	8.853	−3.702 to 21.408	0.166
Number of flap perforators	16.401	9.099–23.704	<0.001
Perforator row			
Lateral row	5.681	−3.792 to 15.153	0.239
Medial/lateral row	25.737	2.683–48.791	0.239
Superficial epigastric vein	17.122	7.462–26.782	<0.001
Recipient anastomosis site (vs. TD)			
Circumflex scapular vessels	−3.608	−18.233 to 11.017	0.628
Internal mammary vessels	23.576	8.058–39.094	0.003
Flap weight	0.052	0.029–0.076	<0.001

TD: thoracodorsal vessels.

and other factors that may be optimized to improve efficiency and reduce the OT.

From our case series, the average length of surgery for a unilateral DIEP flap was 289 min, range 150–550 min. Evaluating the mean OT and the range, it was clear that there were variables that could influence the time of all the procedures.

The time of the individual steps of surgery, including DIEP flap harvest, recipient vessels harvest, anastomosis of vein and artery, flap inset together with mastectomy wound, and abdominal wound closure, was not analyzed because the data were not available for all patients who underwent unilateral reconstruction. This can be considered as a limitation of the study.

Using univariate and multivariate analyses, the LC appeared to be one of the most important variables able to reduce the OT of 13 min for every year with a P values of <0.001. The LC may be supported by a systematic approach developed over the years in order to standardize the procedure, and by a microsurgical breast team adequately trained by the senior author in order to anticipate each step of the procedure.

No statistical difference was observed between immediate and delayed reconstruction and a contralateral symmetrization did not influence the OT ($P = 0.811$).

In our practice, DIEP flap harvest, mastectomy procedure, and recipient vessels dissection are routinely performed simultaneously. The abdominal donor site is closed at the same time with the microsurgical anastomoses. Next, the senior surgeon completes flap insetting, while the assisting surgeon performs the contralateral breast reduction/mastopexy if planned.

Regarding the type of mastectomy, SSM negatively influenced the OT resulting in time increase of 19.57 min on the total procedure while NSM reduced the OT of 22.7 min. This result appeared correlated with the type of flap harvest. An island flap increased the OT of 20 min while an adipose DIEP flap could reduce the OT of 20 min. We can suppose that wound closure take more time in case of SSM or RM/MRM than in case of NSM.

The number of selected perforators depended on perforator's position, diameter of the vein, and the flap volume that was going to be transferred. The number of perforators used to harvest the flap, the use of perforators from both medial/lateral rows, the harvest of the SEV, the use of IMV as recipient vessels and flap weight were negative predictors ($P < 0.001$) to increase the OT.

Rubino et al. (2009) has demonstrated that the bigger is the flap the greater is its flow rate and consequently its venous drainage needs to be higher. Therefore, adding veins in parallel and choosing larger diameter veins are the two main factors that increase drainage from the flap reducing the risk of venous congestion. In the current study, the correlation between flap weight and the number of venous anastomosis was not investigated, but the number of the anastomosed veins by the senior author was related to the aforementioned reasons and it was statistically significant with an increase of OT in time of 37.7 min ($P < 0.001$).

The choice of recipient vessels is one of the key points for microvascular breast reconstruction because flap perfusion and OT depend on their reliability and surgical site. Three types of recipient vessels were used over the time of the study, with the CSV being the preferred recipient vessels in the last few years. Both IMV and TDV are usually easy to expose and have proved equally efficient in this setting because of their suitable caliber and of the possibility to carry out end-to-end anastomosis. The choice is largely up to the reconstructive surgeon and usually based on comfort level and experience, flow characteristics, chest topography, and patient comorbidities. The recent trend in literature claimed the use of IMV as recipient vessels (Lantieri et al., 1999; Moran, Nava, Behnam, & Serletti, 2003; Serletti, Moran, Orlando, & Fox, 1999), even if some authors note unpredictable quality and inconsistency of the internal mammary veins diameter at the level of the fourth rib often necessitating vein grafts (Lorenzetti, Kuokkanen, von Smitten, & Asko-Seljavaara, 2001). Time for vessels' dissection and exposure in immediate reconstruction represents an issue in favor of the axillary vessels. These vessels are accessed contemporaneously with the axillary lymphadenectomy or sentinel lymph node biopsy by the breast surgeon while the harvest of the IMV adds an extra "step" to the surgical procedure. From the data the use of CSV as recipient vessels reduced the OT of 75.4 min ($P < 0.001$) while the use of IMV increased the OT of 55.8 min. As previously reported (Santanelli di Pompeo, Longo, Sorotos, Pagnoni, & Laporta, 2015), our results could be explained by: the greater rate of immediate reconstructions and therefore the easier access to the axillary region since most of the times the general surgeon has already prepared the axillary access to perform sentinel node biopsy or complete lymphadenectomy; and the effect of the LC by the greater use of CSV recently in our practice. All of the above could explain the reduced OTs when the CSV vessels are used. It is obvious that any surgeon has different training and different LC leading to different results than ours.

BMI and patient weight were two important variables to influence negatively the OT, even if they were not negative predictors to increase the OT at multivariate analysis. This result may be due to the fact that bigger is the BMI and patient weight, bigger will be the diameter of the perforator. As a result, a fewer number of perforators will be dissected to flap harvest. This is only an assumption because the correlation between BMI, patient weight, and diameter/number of perforators was not an object of the current study.

A dedicated anesthesiologist reduced the total procedure of 39.63 min ($P < .001$), supporting our idea that a well trained and stable microsurgical team could contribute to optimize the OT, even if it could be not considered as a positive predictor to reduce the OT.

In the current report, intraoperative complications were not observed and were not considered as a potential variable. Even if an intraoperative complication may lengthen the procedure, it cannot be a determinant factor in the statistical analysis unless the intraoperative complication is a common event.

We believe that properly trained staff, including a dedicated microsurgical team, a trained certified registered nurse, scrub technician, and circulating nurse with minimal turn over, facilitates the efficiency of the procedure. A stable team knows step by step the procedure and prevents unnecessary delays such as leaving the operating room to look for instruments or equipment.

A systematic approach to standardize the procedure is also an important issue in case of vascular impairments. The residents and nursing staff have got a specific training course to carry out flap monitoring organized by the hospital management and plastic surgery unit. The hand-held Doppler (Minidop ES-100VX—HadecoVR) examination and clinical observation is performed 1 h for the first postoperative day, 2 h for the next 48 h, 3 h up to 96 h, and 4 h thereafter until planned discharge. Monitoring starts immediately at the end of surgery in the recovery room for 2/3 h and continues at the ward. Residents and nursing staff have to report on a file any clinical flap and handheld Doppler signals changes suggestive for vascular compromise.

Mean time until take-back was 14 h 24 min and of the 16 flaps presenting vascular complications, 13 were successfully salvaged (81.25%). All vascular impairments occurred within the first 48 h in accordance with the findings of Kroll et al. (1996) who recommended that 3–4 days was the optimal length of time required for intensive postoperative microvascular monitoring.

Although microsurgical technique plays an important role, we believe that the implementation of a systematic approach for surgery, preoperative planning, and the adaptation of key intraoperative components can optimize the efficiency of perforator flap surgery for breast reconstruction. The preoperative planning that includes preoperative markings is an important step for surgery as previously reported (Laporta et al., 2015b, 2016); it can help to expedite the entire procedure.

To the best of our knowledge, this is the first 12-year retrospective chart review performed among 404 consecutive patients who underwent immediate and delayed DIEP flap breast reconstruction in order to investigate the associations between predictors and the outcome OT.

5 | CONCLUSIONS

From our results, the increase of flap weight and related number of perforators and venous drainage negatively influenced the OT. LC meaning systematic approach for surgery improved over time, a well-trained microsurgical team and a standardized monitoring protocol optimized DIEP flap surgery efficiency.

CONFLICT OF INTEREST AND DISCLOSURE STATEMENT

We have submitted for publication on International Microsurgery a manuscript entitled: "Time-dependent factors in DIEP flap breast reconstruction." We, hereby certify, that to the best of our knowledge no financial support or benefits have been received by any author, by any member of our immediate family or any individual or entity with whom or with which we have a significant relationship from any commercial source which is related directly or indirectly to the scientific work which is reported on in the article.

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