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Breast

Comparison of Iomeprol-400, Ultravist-370, and Omnipaque-350 in Preoperative Computed Tomography for Visualizing the Deep Inferior Epigastric Perforators

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Background: Breast reconstruction using the deep inferior epigastric perforator (DIEP) flap is considered the gold standard, due to its natural results and minimal damage to the donor site. Precise preoperative imaging to identify optimal perforators is essential for successful DIEP flap surgery, improving surgical outcomes and patient satisfaction. This study evaluates the efficacy of Iomeprol-400, a high iodine concentration contrast agent, against Ultravist-370 and Omnipaque-350 in enhancing visualization of DIEPs on preoperative computed tomography angiography (CTA).

Methods: We performed a retrospective comparative study of 40 female patients who underwent preoperative CTA with contrast injection of Iomeprol-400 and 40 matched controls following the injection of either Ultravist-370 or Omnipaque-350. Arterial phase enhancement in Hounsfield units was measured at the abdominal aorta, proximal and distal deep inferior epigastric arteries (DIEAs), and DIEP. Although measurements were collected at the aorta, these were excluded from statistical analysis due to nonnormal distribution.

Results: Significant differences in arterial enhancement were found between the groups. The Iomeprol-400 group showed higher enhancement at the proximal DIEA ($P < 0.001$), distal DIEA ($P = 0.004$), and at the DIEP ($P < 0.001$).

Conclusions: Iomeprol-400 significantly improves visualization of critical small-diameter vessels in preoperative CTA for DIEP flap surgery compared with Ultravist-370 and Omnipaque-350. These findings support incorporating higher iodine concentration agents such as Iomeprol-400 into preoperative imaging protocols for DIEP flap surgery. *(Plast Reconstr Surg Glob Open 2025;13:e6670; doi: 10.1097/GOX.0000000000006670; Published online 2 April 2025.)*

INTRODUCTION

Deep Inferior Epigastric Perforator Flap Surgery in Breast Reconstruction

Breast reconstruction following mastectomy is a pivotal component of comprehensive oncological care, providing women with the opportunity to restore both physical form and emotional well-being after cancer treatment. Among the myriad techniques available, the deep inferior epigastric perforator (DIEP) flap has become the gold standard in breast reconstruction.[1] This advanced microsurgical intervention involves relocating the patient's skin and subcutaneous tissue from the lower abdomen based on the deep inferior epigastric vessels to form the breast mound. The DIEP closely resembles the natural look and feel of a native breast resulting in a durable breast shape[2] and higher patient satisfaction and quality of life scores.[3–6] Furthermore, this reconstructive surgery spares the rectus abdominis muscle, reducing the risk of abdominal wall weakness and hernia formation, facilitating a quicker recovery, and allowing patients to resume normal activities sooner.[7,8] Additionally, the use of tissue from the lower abdomen

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leads to improved cosmetic outcomes similar to those of a simultaneous abdominoplasty, resulting in a flatter abdominal appearance.[9]

Blood Supply of the Lower Abdomen

Arterial blood supply to the lower abdominal wall originates from the deep inferior epigastric artery (DIEA) and its perforator branches (DIEP). The distal DIEA and DIEP are small vessels with a diameter of around 2 mm[10] that intricately traverse through the layers of the rectus abdominis muscle before reaching the subcutaneous fat and skin of the abdominal wall. These vessels are critical in DIEP flap surgery, supplying the perforators that ensure adequate vascularity and tissue viability for successful breast reconstruction. Through meticulous surgical techniques, one or more of these small-diameter vessels are carefully dissected and utilized to anastomose the tissue from the lower abdomen to the breast mound area, ensuring optimal vascular supply to the transplanted free flap. The precise identification and handling of these DIEP perforator branches are paramount in achieving successful outcomes in microsurgical breast reconstruction while minimizing donor site morbidity. Selecting the portion of the lower abdominal wall for the DIEP flap relies on assessing the location and size of the perforators, considering the variability in vascular anatomy of the abdominal wall between individuals and among the right and left lower abdominal quadrants.[8] Although the proximal DIEA is not typically required for flap harvesting, its visualization plays an important role in preoperative planning, especially in patients with prior abdominal surgery, where tracing perforator continuity to the proximal DIEA is critical. The aorta was included in our study as a potential negative control, as a difference in enhancement between contrast agents was not expected due to it being a larger diameter vessel.

Role of Preoperative Imaging

Preoperative imaging plays a crucial role in surgical planning, as it enables the precise selection of the perforator into the DIEP flap's vascular pedicle. Additionally, it facilitates the identification of the optimal area of the lower abdominal wall with the most robust arterial supply for breast reconstruction.[11] It also provides vital insights into the patient's vascular anatomy, allowing surgeons to plan and execute the procedure with greater precision and efficacy.

A further advantage of preoperative imaging is that it significantly lowers surgical times[12,13] by providing detailed presurgical mapping, which reduces intraoperative decision-making. Several presurgical imaging modalities can help delineate the vascular anatomy of the abdominal wall, including duplex ultrasound, computed tomography angiography (CTA), and magnetic resonance angiography. Among these, CTA with 3-dimensional image reconstruction has emerged as the preferred imaging study.[14] It is readily available, cost-effective, and offers excellent spatial resolution, allowing the demonstration of the location, course, and caliber of the small musculocutaneous perforators necessary to select a suitable vessel.[15]

Takeaways

Question: How do the contrast agents Iomeprol-400, Ultravist-370, and Omnipaque-350 compare in preoperative computed tomography imaging for visualizing the deep inferior epigastric perforators (DIEPs)?

Findings: This retrospective study demonstrated Iomeprol-400's superior image quality and enhanced visualization of the DIEPs compared with Ultravist-370 and Omnipaque-350. The contrast achieved with Iomeprol-400 allowed for more precise identification of vascular structures, facilitating better presurgical planning.

Meaning: Using Iomeprol-400 as a contrast agent in preoperative computed tomography scans for DIEP flap procedures can improve surgical outcomes by providing more detailed imaging, thereby aiding surgeons in planning and executing breast reconstruction surgery more effectively.

Enhancement values measured in Hounsfield units (HUs) have been shown to be strongly associated with improved visualization and delineation of vascular structures on CTA.[16] In the context of DIEP flap planning, clear visualization of the vessel trajectory, including the perforator and its path through the rectus muscle, is critical for both radiologists and surgeons. Such advancements in imaging clarity have contributed to a high concordance—up to 74%—between radiologist recommendations based on CTA and the vessels selected by surgeons for breast reconstruction, highlighting the strong alignment between imaging findings and surgical decision-making.[17,18]

Evaluating the Use of Iomeprol-400 in Preoperative CTA

Until now, contrast agents such as Ultravist and Omnipaque, licensed by the Food and Drug Administration (FDA),[19,20] have been commonly used in DIEP flap presurgical planning. Iomeprol-400 (sold under trade names "Iomeron" and "Imeron") is an approved radiocontrast agent for computed tomography (CT) imaging in most European countries.[21] Although not universally available, it is widely used in many regions and has partial availability in the United States. At the time of manuscript writing, Iomeprol-400 received temporary import approval from the FDA due to shortages of other contrast agents in the United States.[22] At our institution, it is currently used for preoperative abdominal CTA for DIEP, cardiac CT, and transcatheter aortic valve implantation CT.

Iomeprol-400 is distinguished by its high iodine concentration (400 mg/mL),[23] lower osmolality, and viscosity, which reduce chemotoxicity and adverse reactions compared with high osmolar ionic agents.[24,25] Additionally, its high water solubility enables faster excretion, potentially minimizing renal burden.[26] Previous literature also suggests that utilizing contrast agents with elevated iodine concentrations enhances the visualization of small perforator branches.[27] Building upon these findings, our study aims to determine whether administering Iomeprol-400 in preoperative abdominal CTA of the DIEPs provides a substantial benefit regarding arterial enhancement of

these abdominal small-diameter arterial perforators. This will be juxtaposed to the current use of Ultravist-370 or Omnipaque-350 in abdominal CTA scans. We postulate that a discernible difference in contrast enhancement will be found between the 2 groups among the distal smaller diameter vessels, the DIEA and DIEPs. If our hypothesis is confirmed, using Iomepron-400 could serve as a valuable asset for presurgical planning, markedly enhancing outcomes of breast reconstructive surgery for oncology patients on a substantial scale.

METHODS

Study Design and Patient Population

This retrospective case-control study was conducted following formal approval from our institution's ethics committee, and it adhered to established ethical guidelines. Patient consent was waived due to the retrospective nature of the research.

A retrospective search at our tertiary medical center between January 2021 and August 2022 identified all patients who underwent preoperative CTA after administration of Iomepron-400. At our institution, this contrast agent is approved for presurgical abdominal CTA scans in female breast cancer patients scheduled to undergo DIEP flap reconstructive surgery. The control group included 40 female patients 18 years or older, matched for sex and closely matched for age ($P = 0.573$), who underwent abdominal CTA after administration of the contrast agents Ultravist-370 or Omnipaque-350. Individuals with a history of prior aortic surgery, aortic malformations, or acute abdominal aorta pathologies, such as aortic aneurysms or dissection, were excluded from the study.

Ultravist-370 and Omnipaque-350 were combined into a single control group based on their shared characteristic of lower iodine concentration (<400 mg/mL). This study aimed to evaluate whether the higher iodine concentration of Iomeprol-400 resulted in significantly higher enhancement of DIEA and DIEP perforators against agents with lower iodine concentrations. It was hypothesized that the higher iodine concentration would provide superior visualization of the vessel pathway. Although there are slight differences in the iodine concentrations between the control agents, combining them was deemed appropriate to streamline the analysis. This approach not only aligned with the study's objective but also ensured sufficient statistical power by maintaining an adequate sample size in both groups.

Scan Protocols and Imaging Data Collection

All abdominal CTA scans were performed using multidetector CT scanners with automatic collimation, rotation time of 0.4 seconds, automatic scan time, and *z* axis automatic tube current modulation. Three CT scanner models were used in this study: Philips Brilliance iCT 256-slice, Philips Brilliance CT 64-slice, and Siemens SOMATOM Definition AS+ 128-slice CT scanner. Slice thickness followed our institution's established protocols, with 1 mm used in CTA scans performed before DIEP flap surgery for the intervention group and 2 mm in abdominal CTA scans in the control group, conducted for other indications. Precise scan timing was achieved using bolus tracking, with contrast enhancement monitored at the level of the right heart ventricle and the region of interest (ROI) placed at the descending aorta. When the enhancement threshold of 150 HU was reached, the diagnostic scan was initiated after a 5.5-second delay to allow the table to move into position; 100 mL of contrast agent were injected at a rate of 5 mL/s, with slight variations in contrast volume based on the patient's weight. The volume of contrast agent injected was closely matched between the case and control groups ($P = 0.0571$). In both protocols, craniocaudal helical acquisition encompassed the region from the lung bases to the greater femoral trochanter, including the entire pelvis.

Imaging data on arterial phase enhancement were collected using the PACS Carestream Vue v.12.1.5 software. Enhancement was measured in HUs by selecting ROIs at standardized locations, which varied in size (Fig. 1), to match different vessel diameters as outlined in previous literature.[8,10] Arterial enhancement of the abdominal aorta was measured 3 cm above its bifurcation, with a circular 5-mm-radius ROI. The proximal DIEA was assessed bilaterally at its takeoff from the external iliac artery, with a 2-mm-radius ROI. The entrance to the rectus sheath, where the distal DIEA crosses posterior to the inguinal

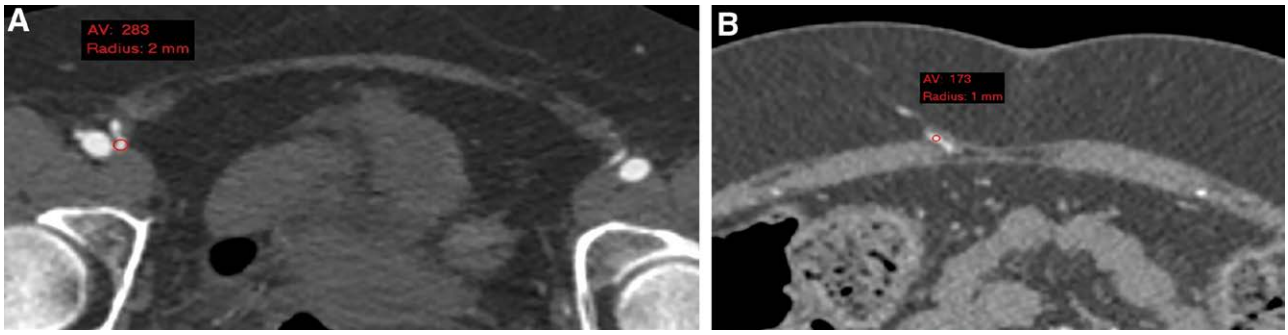

Fig. 1. Examples of arterial enhancement measurements using ROIs at the DIEA and DIEP. The HU values represent the average arterial enhancement within the specified ROI from a single patient. A, An arterial enhancement measurement of 283 HU within a 2-mm-radius ROI at the right proximal DIEA, near its takeoff from the right external iliac artery. B, An enhancement measurement of 173 HU within a 1-mm-radius ROI at the right DIEP, superficial to the right rectus abdominis muscle. AV, average.

ligament, was analyzed using a 1-mm-radius ROI, the smallest allowable on PACS. Similarly, the DIEP flap perforator, just superficial to the rectus abdominis muscle, was examined with a 1-mm-radius ROI. An offsite radiologist, unaware of the specific contrast agent administered evaluated the CTA scans. Their evaluation focused on the scans' technical adequacy, vessel visualization, and arterial contrast enhancement.

Statistical Analysis

Data analysis was performed using GraphPad Prism v.10.2.3 software. Results were calculated using 2-sample *t* tests and displayed as means, SDs, and standard errors. A Shapiro–Wilk test for normality was performed, and results confirmed that our data for the DIEA and DIEP vessels were normally distributed, validating the appropriateness of using the *t* test. The aorta was excluded from our analysis as it did not meet the assumption of normality, a key requirement for the *t* tests used in this study. This approach ensures normal distribution across all datasets, allowing for consistent and reliable statistical comparisons. Moreover, aortic enhancement and visualization are not part of presurgical imaging for DIEP flap surgery, and its exclusion makes the analysis more relevant and avoids potential confusion for surgical readers.

Only participants with complete data for the variables of interest were included in the statistical comparisons between the Iomeprol-400 group and the control group administered Ultravist-370 or Omnipaque-350. The findings are illustrated in tables accompanied by descriptive statistics. All statistical tests were performed at α equal to 0.05 (2-sided), and statistical significance was established for all tests with *P* values less than 0.05.

RESULTS

The demographics, clinical characteristics, and contrast agent volume are summarized in Table 1. Forty patients underwent abdominal CTA following the administration of Iomeprol-400, whereas another 40 control patients underwent abdominal CTA using the contrast agents Ultravist-370 or Omnipaque-350. Both groups were comparable in terms of their demographic characteristics and volume of injected contrast agents. No adverse effects or complications were observed in the cohort following the use of Iomeprol-400.

Table 2 outlines the differences in arterial attenuation, detailing HU values across various segments of the DIEA and highlighting the superior enhancement achieved with Iomeprol-400 compared with traditional contrast agents. These findings are further illustrated in Figure 2, summarizing the study results and underscoring the enhanced arterial attenuation with Iomeprol-400. Significant differences were observed between the 2 groups at the bilateral proximal DIEA, with the intervention group showing higher arterial enhancement than controls ($P < 0.001$). This pattern was consistent in a subanalysis by the abdominal side, where the intervention group demonstrated significantly greater enhancement in both the right and left proximal DIEA ($P = 0.015$ and $P = 0.005$, respectively). For the bilateral distal DIEA, the intervention group had significantly higher arterial enhancement than the controls ($P = 0.004$). Similar results were found in the right distal DIEA ($P = 0.021$); however, the difference in the left distal DIEA was not statistically significant between the 2 groups ($P = 0.082$).

Analysis of the bilateral DIEP revealed a highly significant increase in arterial enhancement for the interventional group compared with controls ($P < 0.001$), as shown in Figure 3. This significant enhancement was also observed in both the right and left DIEP ($P < 0.001$ for both).

DISCUSSION

Higher Arterial Enhancement Using Iomeprol-400

This study evaluated the efficacy of Iomeprol-400 in preoperative abdominal CTA for enhancing arterial visualization of the DIEP flap compared with 2 commonly used contrast agents, Ultravist-370 and Omnipaque-350. Significantly higher arterial enhancement was observed in this study's intervention group for both proximal and distal segments of the DIEA and of the DIEPs. These results suggest that Iomeprol-400 significantly enhances preoperative arterial visualization, particularly in smaller arterial branches such as the DIEPs, compared with the 2 other contrast agents.

The superior arterial contrast enhancement observed with Iomeprol-400 likely stems from its higher iodine concentration (400 mg/mL) compared with Ultravist-370 (370 mg/mL) and Omnipaque-350 (350 mg/mL). These findings align with previous research that correlates higher iodine concentrations with improved opacification in imaging,[27] significantly aiding in the visualization of small vascular structures. In liver cancer imaging, a previous study[28] demonstrated that higher iodine concentrations have been shown to enhance lesion detection and characterization, paralleling our findings in vascular imaging. This study adds to the growing body of evidence

Table 1. Study Population and Volume of Contrast Agent in Abdominal CTA

	Abdominal CTA Scans Following Iomeprol-400 Administration	Abdominal CTA Scans Following Ultravist-370 and Omnipaque-350 Administration	*P*
Patients, n	40	40	N/A
Age, y (mean ± SD)	48.9 ± 8.1	50.4 ± 14.0	0.573
Volume of contrast agent, mL (mean ± SD)	98.5 ± 7.7	94.4 ± 11.1	0.0571

N/A, not applicable.

Table 2. Differences in Arterial Enhancement in Abdominal CTA in the Intervention Group Compared With Controls

Vessel Location	Intervention Group (+) Control Group (–)	N	Mean Arterial Enhancement, HU	SD	SE	*P*
Bilateral proximal DIEA	+	80	254.525	47.747	7.549	<0.001
	–	80	216.438	65.869	10.415	
Right proximal DIEA	+	40	253.55	48.20	7.62	0.015
	–	40	220.05	69.76	11.03	
Left proximal DIEA	+	40	255.50	53.61	8.48	0.005
	–	40	212.83	76.34	12.07	
Bilateral distal DIEA	+	80	237.675	52.162	8.248	0.004
	–	80	205.625	75.312	11.908	
Right distal DIEA	+	40	236.28	54.83	8.67	0.021
	–	40	200.95	77.02	12.18	
Left distal DIEA	+	40	239.08	59.69	9.44	0.082
	–	40	210.30	84.49	13.36	
Bilateral DIEP	+	80	120.625	32.488	5.137	<0.001
	–	80	96.200	21.337	3.374	
Right DIEP	+	40	120.60	35.87	5.67	<0.001
	–	40	95.28	28.13	4.45	
Left DIEP	+	40	120.65	36.16	5.72	<0.001
	–	40	97.13	23.70	3.75	

Values are reported as mean ± SD, standard error (SE), and *P* values obtained using 2-sample *t* tests. The intervention group consisted of female patients who underwent abdominal CTA with the contrast agent Iomeprol-400. The control group consisted of female patients who underwent abdominal CTA with the contrast agents Ultravist-370 and Omnipaque-350.

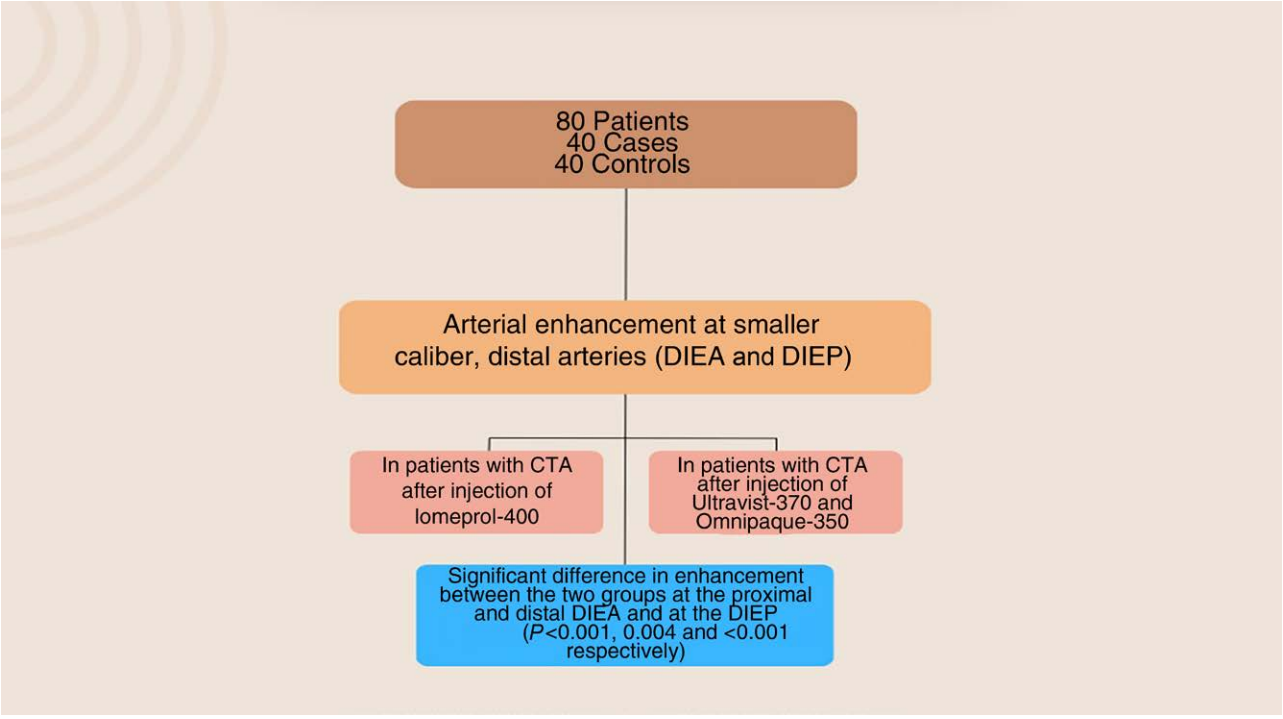

Fig. 2. Study design. Forty female patients who underwent abdominal CTA following intravenous administration of the Iomeprol-400 and 40 female patients in whose scans Ultravist-370 and Omnipaque-350 contrast agent were injected. A significant difference in arterial enhancement was recorded in smaller, distal arteries in the Iomeprol-400 group compared with Ultravist-370 and Omnipaque-350.

supporting the use of higher iodine concentration contrast agents for specific clinical applications where detailed vascular visualization is critical.

Subanalysis by Abdominal Side

The subanalysis by the abdominal side showed consistent results at the level of the right and left proximal DIEA and DIEP, and at the right distal DIEA, with Iomeprol-400 showing significantly higher arterial enhancement. However, no statistical difference between the intervention and control groups was found at the left distal DIEA. This absence of statistical significance might be due to insufficient statistical power, as supported by the presence of statistical significance bilaterally at the level of the distal DIEA.

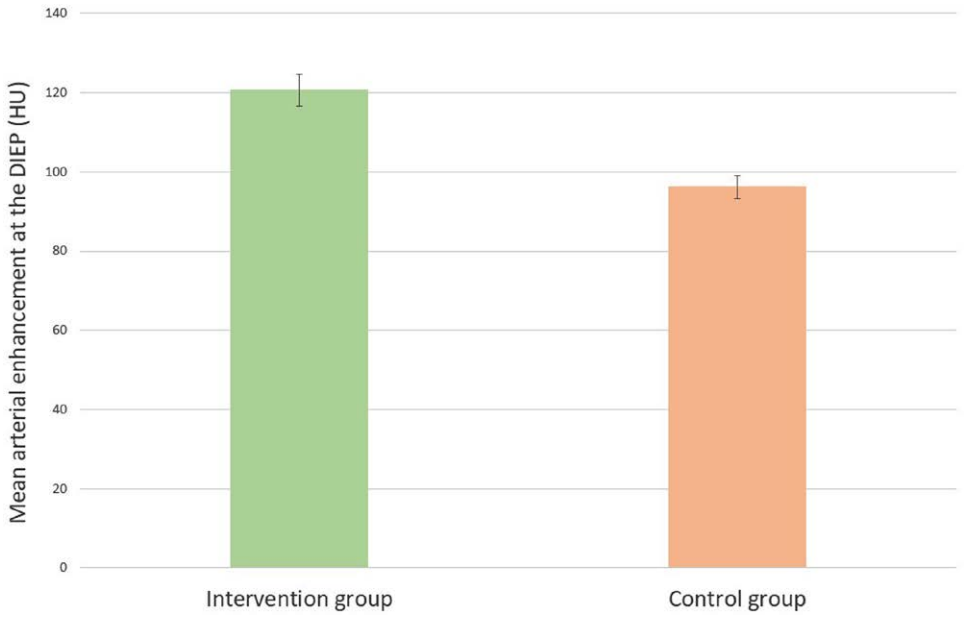

Fig. 3. Comparison of arterial enhancement at the DIEP between the intervention and control groups. Mean arterial enhancement at the DIEP for the intervention group, which underwent CTA scanning after Iomeprol-400 administration, and the control group, which underwent CTA after Ultravist-370 or Omnipaque-350 administration. Mean arterial enhancement was significantly higher in the intervention group (120.6 ± 4.0, mean ± standard error [SE]) compared with the control group (96.2 ± 2.9, mean ± SE), with $P < 0.001$. Error bars in the figure represent the SE.

Clinical Implications

Our findings have important implications for preoperative planning and surgical outcomes in DIEP flap breast reconstruction. Precise identification and dissection of these vessels are crucial for successful tissue transfer.[12] Efficient use of preoperative CTA enables personalized surgical approaches tailored to the unique anatomical characteristics of each patient, reducing operative times,[13] improving outcomes, and minimizing postoperative complications such as postoperative fat necrosis and delayed healing.[29–31]

The enhanced vascular delineation provided by Iomeprol-400 benefits both radiologists and surgeons. For radiologists, the improved contrast supports diagnostic accuracy by highlighting subtle differences in perforator anatomy. For surgeons, it enables precise identification of branching patterns and perforator trajectories, from their takeoff at the anterior rectus sheath to their intramuscular course. This is particularly valuable in patients with prior lower abdominal surgery, such as C-sections, where vessel continuity may be disrupted. By facilitating the selection of optimal perforators, preoperative vascular mapping helps steer surgeons away from less favorable options, supporting more conservative surgical approaches that preserve native tissue and minimize donor site morbidity.[32] Enhanced visualization also minimizes intraoperative adjustments, streamlining procedures and improving overall efficiency.[33]

Safety Considerations

In our study, the iodine load with Iomeprol-400 was within acceptable safety limits, and no adverse events were reported. This aligns with Iomeprol-400's favorable safety profile, characterized by lower osmolality and reduced chemotoxicity compared with high osmolar agents. However, for patients with compromised renal function, routine renal assessments are recommended[34] as part of standard clinical practice to minimize the risk of contrast-induced nephropathy and ensure patient safety.

Study Limitations

Despite the promising findings, our study has several limitations. First, the retrospective design may introduce selection bias; however, efforts were made to mitigate this by closely matching the control group in terms of demographic characteristics.

The sample size, although adequate to demonstrate significant differences, remains relatively small, necessitating more extensive studies to confirm our findings and establish generalizability. The variation in slice thickness between the 2 groups is another limitation. The DIEP protocol uses a slice thickness of 1 mm, whereas regular abdominal CTA scans use a slice thickness of 2 mm. This discrepancy may affect the visualization and assessment of small perforator vessels, which typically have a diameter of around 2 mm. Notably, 2 mm is also the smallest diameter supported on PACS for an ROI. Additionally, this study was conducted at a tertiary center where multiple scanners are routinely utilized for CTA imaging. Specifically, 3 different scanners were used, albeit with the same scanning protocol, ensuring consistency in imaging parameters despite the use of diverse equipment. Future

studies should standardize scan protocols to improve comparability and reproducibility of findings. The exclusion of patients with aortic pathologies, although necessary to ensure a homogeneous study population, may limit the applicability of our findings to a broader patient population.

Future Research Direction

Our study underscores the potential of Iomeprol-400 in identifying perforators. Future research could focus on comparing its clinical concordance with other FDA-approved contrast agents, particularly in relation to intraoperatively selected perforators. Additionally, examining the alignment between vessels identified as optimal on CTA scans by radiologists and those chosen intraoperatively during DIEP flap reconstruction surgery could provide valuable insights into the decision-making process. This alignment may enhance the integration of imaging findings with surgical practices, ultimately improving preoperative planning and patient outcomes.

Future research should also consider additional factors such as side effect profiles and long-term clinical outcomes of using Iomeprol-400 in clinical practice. Finally, the cost implications of switching to a higher iodine concentration contrast agent should be evaluated, considering the potential for improved outcomes against the financial impact on healthcare systems.

CONCLUSIONS

This study demonstrates the potential of Iomeprol-400 as a superior contrast agent for preoperative abdominal CTA compared with Ultravist-370 and Omnipaque-350. The combination of lower viscosity, higher solubility, and improved arterial enhancement offer multiple advantages, making Iomeprol-400 a safe and more effective contrast agent for CTA. These benefits are particularly evident in visualizing smaller arteries, which aids surgical planning and potentially improves outcomes and patient satisfaction.

These promising results support the adoption of Iomeprol-400 in preoperative imaging protocols for DIEP flap surgery, highlighting its potential to improve the success and precision of breast reconstructive procedures. Further prospective studies with larger, more diverse populations and long-term follow-up are needed to fully establish the clinical benefits and cost-effectiveness of Iomeprol-400 in clinical practice.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Haddock NT, Teotia SS. Efficient DIEP flap: bilateral breast reconstruction in less than four hours. *Plast Reconstr Surg Glob Open*. 2021;9:e3801.
2. Evgeniou E, Teotia SS, Haddock NT. Asymmetric four-flap breast reconstruction with DIEP flaps and PAP flaps. *Plast Reconstr Surg*. 2022;150:1236e–1239e.
3. Thorarinsson A, Fröjd V, Kölby L, et al. Long-term health-related quality of life after breast reconstruction. *Plast Reconstr Surg Glob Open*. 2017;5:e1316.
4. Lee MK, Hwang JW, Park JW, et al. Serial comparison of patient-reported outcomes of immediate breast reconstruction: direct-to-implant versus deep inferior epigastric perforator flap. *Aesthetic Plast Surg*. 2023;48:1352–1361.
5. Shiraishi M, Sowa Y, Inafuku N. Long-term survey of sexual well-being after breast reconstruction using the BREAST-Q in the Japanese population. *Asian J Surg*. 2022;46:150–155.
6. Persichetti P, Barone M, Salzillo R, et al. Impact on patient's appearance perception of autologous and implant-based breast reconstruction following mastectomy using BREAST-Q. *Aesthetic Plast Surg*. 2022;46:1153–1163.
7. Howard MA, Mehrara B. Emerging trends in microsurgical breast reconstruction: deep inferior epigastric artery perforator (DIEP) and the superior gluteal artery perforator (SGAP) flaps. *Int J Surg*. 2005;3:53–60.
8. Lam DL, Mitsumori LM, Neligan PC, et al. Preoperative CT angiography and three-dimensional image postprocessing for deep inferior epigastric perforator flap breast reconstructive surgery. *Br J Radiol*. 2012;85:e1293–e1297.
9. Martinez CA, Reis SM, Rednam R, et al. The outpatient DIEP. *Plast Reconstr Surg Glob Open*. 2018;6:e1898.
10. Kim JH, Kim YS, Moon SH, et al. Diametric comparison between the thoracodorsal vessel and deep inferior epigastric vessel in breast reconstruction. *Biomed Res Int*. 2020;2020:1–8.
11. Rozen WM, Ashton MW. Improving outcomes in autologous breast reconstruction. *Aesthetic Plast Surg*. 2008;33:327–335.
12. Clavero JA, Masia J, Larrañaga J, et al. MDCT in the preoperative planning of abdominal perforator surgery for postmastectomy breast reconstruction. *AJR Am J Roentgenol*. 2008;191:670–676.
13. O'Connor EF, Rozen WM, Chowdhry M, et al. Preoperative computed tomography angiography for planning DIEP flap breast reconstruction reduces operative time and overall complications. *Gland Surg*. 2016;5:93–98.
14. Rozen WM, Phillips TJ, Ashton MW, et al. Preoperative imaging for DIEA perforator flaps: a comparative study of computed tomographic angiography and Doppler ultrasound. *Plast Reconstr Surg*. 2008;121:1–8.
15. Cina A, Barone-Adesi L, Rinaldi P, et al. Planning deep inferior epigastric perforator flaps for breast reconstruction: a comparison between multidetector computed tomography and magnetic resonance angiography. *Eur Radiol*. 2013;23:2333–2343.
16. Bolus D, Morgan D, Berland L. Effective use of the Hounsfield unit in the age of variable energy CT. *Abdom Radiol (NY)*. 2017;42:766–771.
17. Boer VB, van Wingerden JJ, Wever CF, et al. Concordance between preoperative computed tomography angiographic mapping and intraoperative perforator selection for deep inferior epigastric artery perforator flap breast reconstructions. *Gland Surg*. 2017;6:620–629.
18. Haddock NT, Dumestre DO, Teotia SS. Efficiency in DIEP flap breast reconstruction: the real benefit of computed tomographic angiography imaging. *Plast Reconstr Surg*. 2020;146:719–723.
19. FDA. Drug approval package: Ultravist (iopromide) NDA #021425. Available at https://www.accessdata.fda.gov/drugsatfda_docs/nda/2002/021425_ultravist.cfm#:~:text=Approval%20Date%3A%209%2F20%2F2002. Published 2002. Accessed June 12, 2024.

20. FDA. Drug approval package: Omnipaque (iohexol) NDA # 18956s28. Available at https://www.accessdata.fda.gov/drugsatfda_docs/nda/pre96/018956-s28_omnipaque_toc.cfm#:~:text=Approval%20Date%3A%207%2F13%2F93. Published 2002. Accessed June 30, 2024.
21. Bracco. Iomeron® (iomeprol). Available at https://www.bracco.com/en-kr/product/iomeron-400. Published 2018. Accessed June 12, 2024.
22. ACR. FDA approves temporary importation of Bracco Iomeprol injection. Available at https://www.fda.gov/media/159925/download. Published July 6, 2022. Accessed March 8, 2025.
23. Bracco. Bracco's Iomeron® (iomeprol) contrast agent optimizes multidetector CT images. Bracco Imaging. Available at https://imaging.bracco.com/us-en/bracco-s-iomeron-iomeprol-contrast-agent-optimizes-multidetector-ct-images. Published 2018. Accessed June 30, 2024.
24. Spinazzi A, Padovani A, Pozzi-Mucelli R. Contrast agents for CT: iomeprol. Clinical pharmacology and applications. *Clin Pharmacokinet*. 2000;59:417–435.
25. Rossiter D, Division of Clinical Pharmacology, South African Medical Association. *South African Medicines Formulary*. 10th ed. Health & Medical Publishing Group, South African Medical Association; 2014.
26. Dooley M, Jarvis B. Iomeprol: a review of its use as a contrast medium. *Drugs*. 2000;59:1169–1186.
27. Solbak MS, Henning MK, England A, et al. Impact of iodine concentration and scan parameters on image quality, contrast enhancement and radiation dose in thoracic CT. *Eur Radiol Exp*. 2020;4:57.
28. Marchianò A, Spreafico C, Lanocita R, et al. Does iodine concentration affect the diagnostic efficacy of biphasic spiral CT in patients with hepatocellular carcinoma? *Abdom Imaging*. 2004;30:274–280.
29. Phillips TJ, Stella DL, Rozen WM, et al. Abdominal wall CT angiography: a detailed account of a newly established preoperative imaging technique. *Radiology*. 2008;249:32–44.
30. Smit JM, Dimopoulou A, Liss AG, et al. Preoperative CT angiography reduces surgery time in perforator flap reconstruction. *J Plast Reconstr Aesthet Surg*. 2009;62:1112–1117.
31. Uppal RS, Casaer B, Van Landuyt K, et al. The efficacy of preoperative mapping of perforators in reducing operative times and complications in perforator flap breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2009;62:859–864.
32. Teunis T, van Voss MRH, Kon M, et al. CT-angiography prior to DIEP flap breast reconstruction: a systematic review and meta-analysis. *Microsurgery*. 2013;33:496–502.
33. Ogunleye AA, Deptula PL, Inchauste SM, et al. The utility of three-dimensional models in complex microsurgical reconstruction. *Arch Plast Surg*. 2020;47:428–434.
34. American College of Radiology (ACR) and National Kidney Foundation (NKF). ACR-NKF consensus statement on use of iodinated contrast media in patients with kidney disease. ACR Clinical Resources. Available at https://www.acr.org/-/media/ACR/Files/Clinical-Resources/ACK-NKF-Consensus-Iodinated-Contrast.pdf. Published 2020. Accessed December 20, 2024.