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ORIGINAL ARTICLE

Analysis of vein grafting versus arteriovenous loop in microvascular head and neck reconstruction: Multicenter series of 36 patients

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Abstract

Background: The utilization of an arteriovenous loop is an underreported technique that affords the creation of reliable vascular options. Understanding the efficacy and impacting variables of microvascular reconstruction with an arteriovenous loop can be critical to its use.

Methods: Multi-institutional study of 36 patients who underwent vein grafting or AV loop with free tissue transfer.

Results: 58.3% of patients received prior radiation and 38.9% prior flap reconstruction. Flap success for vein grafting was 76% and AV loop was 100% ($p = 0.16$). Success for the radiated cohort was 90.5% and non-radiated 80% ($p = 0.63$). Flap success for the radiated, vein grafted patient was 83.3% and 100% flap success rate for radiated, AV loop patient ($p = 0.49$). Overall flap survival was 83.3% versus 97% overall success rate in the United States.

Conclusion: The AV loop is a viable modality for vessel-depleted free tissue reconstruction. Radiation and previous surgery do not significantly impact flap success rates.

KEYWORDS

arteriovenous loop, free tissue transfer, microvascular reconstruction, radiation, vessel depletion

1 | INTRODUCTION

With success rates ranging from 91% to 99% nationally and globally, free tissue reconstruction has become commonplace in the reconstruction of head and neck defects following ablation, trauma, and complex wound management.[1–7] Radiotherapy coupled with prior neck dissection may result in a lack of suitable local vasculature

for reconstructive microsurgery.[8,9] Depleted vascular targets close to the ablative field may necessitate utilizing vessels farther away, often requiring vein grafts.

The use of vein grafts, often saphenous or cephalic, have been previously described in the literature to facilitate microvascular reconstruction by bridging gaps between the donor and recipient vessels as well as creating alternate vascular conduit from larger bore vessels.[1,3,4,10–17] When both the artery and the vein require grafting, simultaneous vein grafts can be placed, or an arteriovenous loop can be created for later use following a brief period of maturation. Although the concept has been described previously, larger scale studies specific to the head and neck have yet to be reported. Simultaneous vein grafts can be created utilizing a single long vein that is divided into two venous extension conduits that can then be anastomosed to the free flap pedicle in the same index operation. Application of an arteriovenous loop involves the creation of a venous loop graft in one sitting, allowing for a short period of maturation, and then returning to the operating room for loop division and reconstruction. The utilization of an AV loop essentially allows for two venous extension grafts that have been allowed a period of maturation in order to minimize anastomotic variables.

We present a multi-institutional series of 36 patients who have undergone microvascular reconstruction with vein grafts or an AV loop in the setting of vessel depletion. In this manuscript, the authors' outcomes and techniques will be discussed along with a comparative analysis of both techniques.

2 | MATERIALS AND METHODS

Institutional Review Board approval at each institution was obtained prior to initiating the study. A retrospective multi-institutional analysis was conducted on 36 patients who underwent free tissue transfer utilizing an arteriovenous loop graft or a simultaneous artery and venous extension vein graft between the 1999 and 2021. Written informed consent was also obtained for patient photographs and data to be utilized in the creation of this manuscript and for additional educational and research purposes.

Free tissue reconstruction was performed at three tertiary care centers by the microsurgical reconstruction teams: Miami Valley Hospital (Dayton, OH), Baylor Medical Center (Fort Worth, TX), and Oregon Health Science University (Portland, OR). The arteriovenous loop creation and vein grafting was performed by either the primary microsurgical team or by vascular surgery. In patients undergoing extension vein grafts, a single graft was utilized to create a conduit between artery and vein, and subsequently divided to yield two extension grafts in the index operation. In patients undergoing an arteriovenous loop, a similar conduit was formed, but division was not performed till 5–7 days later to allow for maturation.

The source of vein graft, type of flap, final outcome, radiation therapy, and timing of the vein graft anastomosis to neck vessels were recorded. A minimum follow-up of 2 months was required and flaps were considered viable if alive at 2 months.

Vein grafting was most commonly utilized for oncologic purposes given traditional preference to perform ablative surgery, neck dissection, and reconstruction in the same sitting.

Arteriovenous loop technique was more commonly utilized for chronic wound restoration or for patients in whom final margin analysis was sought prior to reconstruction. For instance, in a patient with scalp melanoma, the loop was created at the time of the scalp resection in order to await final margins, while the reconstruction was performed 1 week after. Unless a locoregional flap was being utilized following ablative resection and neck dissection, as in cases when bony mandibular reconstruction was delayed, wound care was performed during this time frame. In cases of scalp reconstruction, the loop was banked in the pre-auricular soft tissue by simply placing the loop in that region and closing the skin overlying it. The closure of the skin generally kept the loop in the appropriate orientation; however, in certain scenarios, a small prolene suture was placed by vascular surgery at the apex of the loop to keep it secured superiorly. In cases where the loop was banked in the neck, it was simply allowed to rest in a favorable curvature. The carotid flow was generally sufficient to keep the loop patent and resistant to compression.

The time between loop creation and the definitive reconstruction was approximately 5–7 days. At this time frame, enough time had passed to confirm patency of the loop while preventing the challenges of intimal hyperplasia and arterialization which can occur with long term graft maturation. During the maturation period, the AV loop would be checked periodically with Doppler to ensure patency. Figure 1 displays an intraoperative photograph of an arteriovenous loop prior to anastomosis of the flap vasculature and immediately following the anastomosis of the flap pedicle.

2.1 | Statistical analysis

A university-based biostatistician determined the appropriate methodology of data interpretation. To determine statistically significant differences in flap viability among

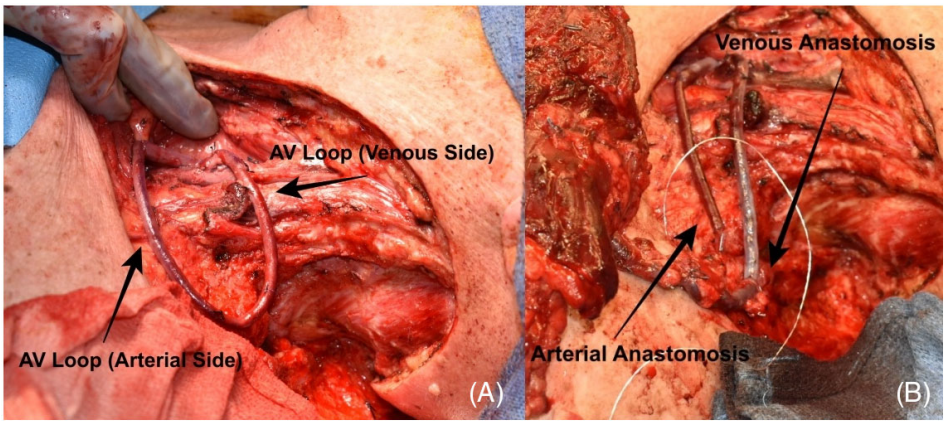

FIGURE 1 Creation of arteriovenous loop with cephalic vein graft prior to microvascular anastomosis of the flap pedicle (A). Post-anastomotic photograph following division of the loop graft into arterial and venous limbs followed by anastomosis with flap pedicle (B). *Source*: Photo used with permission.[1] [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Comparison of flap survival between vein graft and AV loop reconstruction.

Surgical technique	Vein grafting	26 patients	72.2%
	AV loop	10 patients	27.8%
Vein graft outcomes	Flap survival	20 patients	76.9%
	Flap failure	6 patients	23.1%
AV loop outcomes	Flap survival	10 patients	100.0%
	Flap failure	0 patient	0.0%
Statistical comparison with chi-square test	At $\alpha = 0.05$, 2-tailed test $p = 0.1567$ and 1-tailed test $p = 0.1182$		
	No statistically significant difference		

TABLE 2 Comparison of flap survival between radiated and non-radiated patients.

Radiation	Yes	21 patients	58.3%
	No	15 patients	41.7%
Radiated outcomes	Radiated flap survival	19 patients	90.5%
	Radiated flap failure	2 patients	9.5%
Non-radiated outcomes	Non-radiated flap survival	12 patients	80.0%
	Non-radiated flap failure	3 patients	20.0%
Statistical comparison with chi-square test	At $\alpha = 0.05$, 2-tailed test $p = 0.6296$ and 1-tailed test $p = 0.3375$		
	No statistically significant difference		

patients being treated in single versus staged operations, and to examine the role of radiation in flap viability, a chi-square test with a fisher correction was employed given the sample size in this population.

3 | RESULTS

Thirty-six patients met inclusion criteria. The majority of patients were reconstructed following ablation for oncologic reasons 80.5%. The fibula flap was most commonly used with the latissimus dorsi and ALT flaps as second and third most common, respectively.

Twenty-six patients (72.2%) underwent a single stage operation wherein the vein grafts were created and utilized during the same sitting, while 10 patients (27.8%) underwent a staged repair wherein the creation of the arteriovenous loop graft and the final reconstruction were separated by a period of 1–3 weeks. It is important to note that none of the loops had thrombosed during the maturation period between stages. The prevailing donor choice for vein grafts and arteriovenous loop creation was the saphenous vein (50%) with the cephalic vein being the second most commonly employed option (27.8%). The facial vein and external jugular vein were also utilized in select cases. Lastly, 21 patients (58.3%) had undergone prior radiation while 15 patients (41.7%) had not been radiated. All arteriovenous loops were created between the common carotid artery and internal jugular vein. In the majority of vein grafting procedures, facial artery and vein were utilized with a small subset involving the thoracodorsal vessels (12%) or superior thyroid (4%). All flap failures, namely in the vein grafting group, involved the utilization of the facial artery and vein with one patient failing after use of the thoracodorsal vessels.

Twenty-five patients had veins harvested and conduits created by the head and neck surgery team, while 11 patients underwent harvest and creation with vascular surgery. All of the venous extension grafts were created by head and neck surgery, and all of the AV loop procedures involved vascular surgery. 76% (19/25) flap survival was noted in the conduits created by head and neck

TABLE 3 Comparison of flap survival between vein grafting and AV loop reconstructions performed on patients with prior radiation history.

Radiated vein graft outcomes	Flap survival	10 patients	83.3%
	Flap failure	2 patients	16.7%
Radiated AV loop outcomes	Flap survival	9 patients	100.0%
	Flap failure	0 patient	0.0%
Statistical comparison with chi-square test	At $\alpha = 0.05$, 2-tailed test $p = 0.4857$ and 1-tailed test $p = 0.3143$ No statistically significant difference		

surgery (vein grafts) and 100% (11/11) survival was noted in the conduits created by vascular surgery (AV loop). These numbers, however, were not significantly different given the small sample size and discrepancy in comparison groups.

When examining the entire cohort, 30/36 (83.3%) flaps survived. Seven of these patients were revised in the operating room in the immediate postoperative period with successful salvage of all but one patient (86%).

Examination of staging AV loop creation and flap reconstruction was compared to patients undergoing single stage vein grafting. Twenty-six patients who underwent vein graft augmented reconstruction (20/26, 77% survival) were compared to 10 patients (10/10, 100% survival) who underwent an AV loop based approach. Table 1 displays a summary of the comparison characteristics. There was no significant difference in flap survival based on surgical methodology. Tables 2 and 3 show that radiation had no significant effect on flap survival overall or when stratified by type of technique. Overall flap survival in this study was approximately 83%.

4 | DISCUSSION

The overall success rate of free flaps in the head and neck is approximately 91%–99% in a naive untreated neck.[1,5–8] Free tissue reconstruction in the setting of a previously radiated and multiply operated neck can be an extremely difficult challenge for the reconstructive surgeon. However, the outcomes in experienced hands still appear to be favorable and are reported at 90%–95%.[1,5–8]

The true challenge arises in the setting of the multiply treated neck whereby vascular options for microvascular reconstruction are difficult to dissect, beyond the reach of the vascular pedicle, or unavailable altogether. In cases where vessels are accessible in the neck but beyond the reach of the vascular pedicle, a vein graft has been employed to create a vascular conduit that can serve as both arterial donor and venous recipient. The greater saphenous and cephalic veins are two of the most used veins in these scenarios. The saphenous is readily accessible for harvest and offers length and caliber, while the cephalic allows for more pliability and a more similar vessel diameter match for microsurgical free flap anastomoses. Previous studies have shown success rates of free flaps with a single vein graft to range from 85% to 95%, with one study reporting a 100% success rate when only reviewing the use of the cephalic vein.[18–21] However, literature comparing outcomes based on donor vein is lacking. Another option when both venous and arterial options are scarce is to employ an AV loop which, in previous studies, has shown a free flap success rate ranging between 80% and 100%.[4,13,18–20]

The use of AV grafts to facilitate free tissue applications in head and neck reconstruction has previously been described in the literature.[1,4,5,9–11,17] Creation of an autologous AV loop graft can be the precursor for immediate simultaneous vein grafting or a delayed maturation yielding a true arteriovenous fistula. At the authors' institution, it is generally preferred to perform this second-stage definitive free flap reconstruction approximately 1 week following AV loop graft creation. In previous patients where second stage reconstruction was delayed beyond 2–3 weeks, it was noted that additional scarring and thickening of the vein graft was apparent.

Though the use of extension vein grafts, for artery and/or vein, is part of the armamentarium of all microsurgeons, using an AV loop has not been widely reported in the literature given that most studies have focused on a single vessel being grafted. More specifically, there have also not been studies examining vein grafting compared to AV loop use. Moubayed et al. performed a study involving nine patients who underwent AV loop for head and neck reconstruction with 100% free flap success over a 10-year time span.[4] The emphasized theoretical advantage of this type of approach is hinged on the minimization of microanastomotic variables, namely the two anastomoses at the takeoff of the arteriovenous loop. In a delayed fashion, the variables that remain are the arterial and venous anastomosis between the loop and the flap, similar to any microsurgical reconstruction. In the immediate simultaneous vein graft approach, the addition of the anastomoses at the takeoff of the extension grafts yield four potential anastomotic sites that could be compromised.

Conversely, a systematic review by Knackstedt et al. and retrospective study by Oswald et al., which both included AV loops outside of the head and neck, suggested a single stage vein graft application as the optimal approach.[12,22] Knackstedt et al. stated a statistically higher rate of major complications and failures in staged

procedures involving an AV loop. Overall, current literature of AV loop utilization specific to the head and neck is limited and yet to involve a large sample size.[4,12,22]

In the present study of 36 patients, the authors report an 83% success rate when examining both vein grafts and AV loop utilization for complex microvascular head and neck reconstruction. While it did not achieve statistical significance in the present study, there may be theoretical advantages in using an AV loop to augment definitive free tissue reconstruction. Staging these procedures, the creation of the loop graft to the definitive reconstruction, allows one to minimize the number of variables, taking the "hostility" out of the multiply treated neck by the de novo creation and maturation of a new donor and recipient vessels. In order the improve the feasibility of staging, utilizing preoperative CT angiogram or duplex ultrasound of the neck may elucidate patients with questionable vasculature. Importantly, for patients with anticipated reconstruction for oncologic needs, the question may arise as to the planning of the loop creation with neck dissection so as not to disrupt the complete oncologic operation. In this scenario, the authors have suggested that an AV loop can be created out of the oncologic field 1 week prior to surgery, which ultimately would provide for favorable vasculature without delaying oncologic treatment. For example, in a patient needing a radial forearm free flap for an anticipated glossectomy defect, if concern arises regarding the vessel status preoperatively, an AV loop can simply be created in the contralateral neck, or ipsilaterally using subclavian or axillary vessels if desired.

Additionally, the AV loop approach may reduce the amount of operative time in a single setting, which may yield benefits to overall flap success and minimize an insult to co-morbid conditions. The goal of reduced operative time, especially when less than 12 h per Offodile et al., optimizes early flap success and overall patient outcomes.[23]

These conjectures are currently based on experience; the data analyses in this study did yield a statistically significant difference between these two techniques. Bothtechniques have been successfully performed by the surgeons in this study. Ultimately, surgeon preference combined with key patient factors may dictate the appropriate algorithm.

Multiple studies in the literature have compared free flap outcomes between a virgin and previously treated neck. One retrospective study by Kim et al. illustrated a 98.8% success rate of free flap reconstruction for primary cancer treatment and 95.2% for recurrent cancer, with no significant effect of previous radiotherapy or surgery on the overall flap survival.[8] Alternatively, Shankhdhar highlighted a 90.8% flap success rate in the previously treated neck, which was associated with an increase in re-exploration rates in the postoperative period.[5] In the current study, radiation and prior treatment did not affect overall flap survival in a statistically significant fashion, consistent with the findings from the above studies.

The degree of impact of radiation therapy on free flap viability remains controversial.[5,6,24,25] The physiologic and anatomic damage related to radiation on the vasculature is well established and potentially creates a more difficult surgical field. However, several studies have suggested that radiation therapy does not pose obvious adverse outcomes for free flap reconstruction.[24,26] Choi et al. involved a cohort of 100 patients receiving a fibular free flap and noted no significant differences in postoperative complication rates between preoperative radiated, postoperative radiated, and non-radiated groups.[24] There are no studies to date discussing the impact of radiation on vein grafts or AV loop free flap success in the head and neck. In this study, an approximately 90% free flap success rate was reported in the radiated neck, versus 80% success rate in the non-radiated neck. Although not statistically significant, these findings suggest that a history of radiation does not adversely affect free flap viability when either of the techniques in this paper are utilized.

Although the present study examined a larger cohort than previously reported, the continued limitation of a small sample size requires further evaluation to make robust conclusions that may be broadly applicable. A larger sample size, and one stratified by similar characteristics and subject size, could allow for a more high-powered study to make broad generalizable recommendations fitting of the population. Another important limitation to mention is of course, selection bias. In this study, the specific technique utilized was surgeon dependent. One of the surgeons in this study routinely created their own grafts and performed single stage reconstruction. Another surgeon in this study, however, opted for vascular surgery to perform the loop creation, with the reconstruction occurring in a staged fashion. This selection of technique was not evenly distributed and solely dependent on surgeon/institution preference. In the future, larger scale studies may be performed to control for selection bias while also examining additional variables such as donor graft choice, recipient vessel choice, and surgical sub-specialty.

Despite the limitations of this study, the techniques described show promise and have been a useful adjunct from the authors' experience. With appropriate planning, workup, and patient selection, the use of an arteriovenous loop can augment microsurgical head and neck reconstruction in the vessel depleted neck.

5 | CONCLUSION

Based on the results of this multi-institutional study, the utilization of vein grafts or an arteriovenous loop yield an overall 83% flap success rate and provide an alternative vascular option in the previously treated neck. Radiation history does not seem to impact flap success in this population. While there may be theoretical advantages to utilizing an arteriovenous loop, the data has not borne out a statistically significant advantage in this study.

AUTHOR CONTRIBUTIONS

All authors have reviewed the manuscript and approve of its submission to Head and Neck.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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