Autologous breast reconstruction beyond the DIEP: a narrative review of autologous breast reconstruction options beyond the DIEP flap

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Abstract: The field of breast reconstruction has undergone tremendous advancement over the years both in terms of prosthesis-based reconstruction as well as autologous breast reconstruction. In the modern era, the abdomen represents the most commonly used donor site for autologous breast reconstruction. The traditional transverse rectus abdominis myocutaneous (TRAM) flap has been gradually replaced with muscle-sparing flaps of the abdominal musculature in hopes of minimizing donor site morbidity. The muscle-sparing TRAM, deep inferior epigastric perforator (DIEP) flap, and superficial inferior epigastric artery (SIEA) flap have gained in popularity, with the DIEP representing the gold standard in autologous microvascular breast reconstruction. However, in certain circumstances a traditional DIEP may not be possible, and modifications and alternate donor sites have to be considered. The goals pursued by any breast reconstruction should consider the following aspects: symmetry, shape, ptosis, natural movement, softness and sensitivity. This review aims to discuss the evolution and innovation in the abdominal donor site as well as to introduce alternate donor sites that can be used for free tissue breast reconstruction. Our purpose is to analyze the various alternative options that can be used in breast reconstruction considering the advantages and the disadvantages of each flap. This review can help plastic surgeons to construct an algorithm for choosing the appropriate alternative free flap for breast reconstruction when the DIEP flap is not available.

Keywords: Alternative flaps; microsurgery; autologous breast reconstruction; free flap

Introduction

Although the overwhelming majority of breast reconstructions performed in the United States are implant-based, autologous breast reconstruction is considered the gold standard by many reconstructive plastic surgeons (1-4). The use of the patient's own tissue has distinct advantages over implants including a more natural feel and appearance, and a more durable reconstruction without concerns regarding device failure, capsular contracture, and the need to exchange the implants during the patient's lifetime (1-3,5).

Regarding the abdominal donor site, a flap based on the deep inferior epigastric vessels is preferable to a pedicle flap based on the superior epigastric vessels which has been associated with higher fat necrosis rates as well as higher donor site morbidity (1,3).

With the increased comfort in perforator flaps and perforator dissection, as well as improved outcomes in microvascular techniques, the use of microvascular free

flaps has revolutionized the field of breast reconstruction (3,6,7). At most high-volume institutions, success rates in free flap breast reconstruction exceed 95% (7). Given these outcomes, the contraindications continue to dwindle while patients previously deemed as unsuitable candidates are now able to receive autologous reconstruction safely and successfully (7). However, in certain circumstances, the abdominal donor site may not be usable due to prior abdominal surgery, body habitus, or prior flap harvest (6,7). In these situations, modifications to the abdominal donor site and alternate donor sites have emerged as viable options for free flap breast reconstruction (6,7).

The present review aims to provide a thorough synopsis of available donor sites in autologous breast reconstruction beyond the traditional deep inferior epigastric perforator (DIEP) flap with a focus on considerations of each donor site to guide reconstructive surgeons in counseling patients interested in autologous breast reconstruction.

Over the years, the main concerns in selecting an alternative flap for breast reconstruction were the donor site morbidity, the shape of the body, the difficulty of the flap's harvest technique and the possibility of reconstructing a sensate breast. After a thorough analysis of the literature data, this review can also help plastic surgeons in following an algorithm for choosing the appropriate free flap for each patient. We present the following article in accordance with the Narrative Review reporting checklist (available at http://dx.doi.org/10.21037/abs-20-66).

Methods

In writing this review article, we used the PubMed and google scholar sources, by searching for the following keywords: free flap breast reconstruction, autologous breast reconstruction, alternative free flaps for breast reconstruction, nonabdominally-based flaps for breast reconstruction, innovations in breast reconstruction. We analyzed articles published in English, mainly in the last 20 years, reviews or original articles, that best described harvest techniques, complications, tips and tricks for a safe harvest, management of donor site morbidity.

Preoperative evaluation and history

For any patient undergoing surgery, a thorough history and physical is warranted, but in terms of microvascular reconstruction, consideration should be given not only towards the initial reconstruction, but also for the possibility of reoperation in the setting of compromised perfusion to the free flap (3,7). For these reasons, during the history, patients should be asked regarding prior thrombotic events or multiple unplanned miscarriages or spontaneous abortions which may be indicative or a hypercoagulable condition (8). Numerous factors that were previously considered contraindications to free flap breast reconstruction have been largely discredited given the increased experience and knowledge surrounding free tissue transfer (2,7,9).

Nonetheless, patients should be carefully counseled regarding the longer operative and recovery time with autologous reconstruction compared to an implant-based reconstruction (1,4). Comorbidities such as diabetes, hypertension, and smoking have not been associated with increased risks for flap loss, but they can certainly impact wound healing (1,2,5,10,11). Obesity has also long been considered a contraindication to autologous breast; however, again, recent evidence suggests that morbidly obese patients can still undergo microvascular breast reconstruction safely with limited complications and high success rates (11-15). While patients should be encouraged to lose weight, studies examining device-based reconstruction in obese patients have demonstrated significantly higher complication rates, making autologous reconstruction the preferred approach at the authors' institutions.

Another important consideration for patients interested in undergoing breast reconstruction is the impact of adjuvant therapies (16). Patients who are on hormonal therapy may need to consider discontinuing their tamoxifen for 2 weeks prior to reconstruction and potentially even prolonging the hiatus for an additional 2 weeks following reconstruction (16,17). Again, earlier data had demonstrated increased risks of microvascular thromboses, while more recent studies have not corroborated those findings (16,17). While some studies have demonstrated that radiation therapy has limited detriment to the flap, others have found significant shrinkage and fat necrosis in flaps subjected to radiation which may require additional surgeries and revisions (4,16,18). In general, it is preferable to proceed with definitive reconstruction following completion of radiation (1,4,16,18). One approach is to perform a completely delayed reconstruction following a total mastectomy, or alternatively, a delayed-immediate approach can also be employed by using a tissue expander at the time of the skin-sparing mastectomy (2,4,16,18,19). Following adjuvant radiation to the tissue expander, the authors recommend delaying reconstruction for a minimum

Table 1 Characteristics of autologous breast reconstruction flaps

Flaps	DIEP	SGAP	IGAP	LTP	PAP	TUG	LAP
Dissection difficulty	Low	High	Moderate	Low	Moderate	Low	High
Pedicle caliber mismatch	No	Yes	Yes	No	Yes	Yes	Yes
Need for position changes	No	Yes	Yes	No	No	No	Yes
Sensitivity	Lower intercostal nerves	Superior cluneal nerves	Branches of inferior gluteal nerve (S1–S2)	Lateral femoral cutaneous nerve	Posterior femoral cutaneous nerve	Cutaneous branches of the obturator nerve	Superior cluneal nerves

DIEP, deep inferior epigastric perforator; SGAP, superior gluteal artery perforator; IGAP, inferior gluteal artery perforator; LTP, lateral thigh perforator; PAP, profunda artery perforator; TUG, transverse upper gracilis; LAP, lumbar artery perforator.

of 6 months prior to proceeding with an autologous reconstruction given the increased risks of complications seen when attempting reconstruction earlier. Unfortunately, subjecting patients to multiple operations is a factor that should be discussed and considered when evaluating patients for reconstruction (2,18).

Physical examination and work up

All patients, regardless of the modality of reconstruction, should undergo a thorough physical exam including the breasts as well as the potential donor sites (2). From an oncologic perspective, the breasts should be examined for any palpable masses, skin changes, nipple retraction or discharge, as well as an exam of the axilla for any lymphadenopathy (2). From a plastic surgery perspective, it is important to evaluate the size, symmetry, degree of ptosis, and any prior scars from prior surgeries. The contralateral breast should also be examined both oncologically and for reconstruction, and studies have demonstrated procedures aimed to restore balance and symmetry can be performed safely and simultaneously with the free flap (20,21). Patients should also have appropriate diagnostic imaging of both breasts (19,20). In patients presenting for delayed reconstruction, the pliability and condition of the skin should also be evaluated, particularly in patients who have had prior radiation (2,19).

The physical exam should obviously also consider the available donor sites for autologous reconstruction (2). As the abdominal donor site is the most popular, the abdomen should be examined for scars from prior surgeries (2,22). For patients who have had any type of abdominal surgery, we recommend obtaining a CT angiogram to evaluate the

vascular anatomy and perforators preoperatively (22-24). Patients who have had prior liposuction in the abdomen should be counseled regarding the potential risks of fat necrosis in their reconstructed breasts (22,23). Patients who have had a formal abdominoplasty are generally not candidates for an abdominal-based free flap (22).

In this setting, a number of additional donor sites have emerged and been found to be excellent alternatives to the abdomen in autologous breast reconstruction (*Table 1*) (7). Alternate donor sites that should also be examined are both the superior and inferior gluteal regions, the medial and lateral thigh, and the lower back and flanks (1,3,7). Patients who are not candidates for a DIEP flap may be candidates for a superior gluteal artery perforator (SGAP) or inferior gluteal artery perforator (IGAP) flap (25,26). Or for patients who carry more adiposity in the medial or lateral thigh, the transverse upper gracilis (TUG), profunda artery perforator (PAP) or lateral thigh perforator (LTP) flaps are also reasonable options (7,27,28). Finally, the lumbar artery perforator (LAP) flap is gaining more popularity as a potential donor site for breast reconstruction (29).

Whether one decides to obtain preoperative imaging is largely at the discretion of the reconstructive surgeon, but studies have demonstrated benefits to preoperative planning where the vascular anatomy and perforators of the donor site are identified using a CT or MR angiogram (30,31). The utility of such imaging studies should be weighed against the added costs but are highly recommended for the novice microsurgeon or when embarking on one of the less commonly performed flaps for the first time (30). In general, we recommend imaging when patients have had prior surgery in the donor site, including liposuction, and for gluteal and lumbar flaps (23,31). For patients
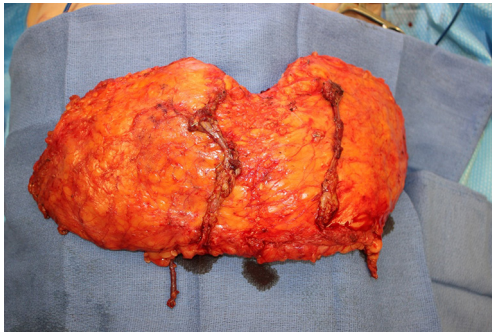
Figure 1 Bipedicle DIEP flap. DIEP, deep inferior epigastric perforator.

undergoing a medial thigh-based flap, preoperative imagine is recommended if the flap is harvested in transverse orientation (30,31).

Imaging of the recipient site is generally only considered in the setting of delayed reconstruction in the radiated chest (32). The authors routinely use the internal mammary vessels as the recipient vessels rather than the thoracodorsal vessels that should be preserved so a pedicled latissimus dorsi myocutaneous flap can still be performed in the setting of a total flap loss. Careful consideration and imaging may be helpful, particularly when one is proceeding with reconstruction of the left breast following a mastectomy and radiation (32). The left internal mammary vein (IMV) is significantly smaller compared to the right side, and an alternate venous outflow may be necessary if the IMV is not usable or diminutive (33). If the IMV is less than 2 mm in size, the authors recommend an alternate recipient vein, such as the cephalic vein which can generally be dissected using stair-step incisions down to the antecubital fossa and reach the medial chest without difficulty (34). Based on basic physic principles (Poiseuille's law), this is preferable to performing two smaller anastomoses to internal mammary vessels in an antegrade and retrograde fashion.

Donor sites

Abdomen

The abdominal donor site represents the most popular donor site for autologous breast reconstruction for a number of reasons including the ample tissue in terms of both skin and volume that can be harvested with limited donor site morbidity (35). For many patients the post-operative abdominal contour is a secondary benefit to the operation (35,36). Traditionally, one hemiabdomen is utilized to reconstruct a single breast (36). The use of indocyanine green (ICG) has revolutionized the ability to decipher the perfusion of flap and can be beneficial in perforator selection and determining whether the perfusion needs to be augmented. In the setting that the traditional DIEP cannot be performed due to compromised perfusion across the midline, or in the setting of prior surgery, a modification to the traditional DIEP can be performed (22,23). Similarly, for patients who do not have sufficient volume to reconstruct a breast of appropriate size or if patients present for delayed reconstruction in the setting of prior radiation, more skin and volume may be necessary (37,38).

The bipedicle DIEP flap represents a modification to the traditional DIEP flap where the entire abdominal tissue is harvested as a single flap to reconstruct a unilateral breast (*Figure 1*) (37-42). The authors prefer to leave the flap in continuity to maximize perfusion to the entire flap and also to allow for shaping of the breast with preservation of the skin. Alternatively, the concept of "stacking" flaps has also been increasing in popularity and can be performed with bilateral DIEP flaps as well as with other alternative flaps in order to obtain the necessary volume (36,38,40-42). In this setting, one flap is completely buried to add projection and volume to the reconstructed breast (40-42).

The authors favor using the internal mammary vessels in an antegrade and retrograde fashion. Alternatively, if there are two IMVs of suitable size, both veins can be connected in an antegrade fashion, or if sizable internal mammary perforators are available, they can also serve as the recipient vessels for one of the pedicles of the bipedicle flap (41-43). In general, removal of the cartilage of a single rib is adequate to provide sufficient length to perform both anastomoses if the soft tissue is removed in the 2nd and 3rd intercostal spaces (42,43).

Closure of the donor site should be performed carefully in order to minimize the risks of a bulge or hernia (1,39,44,45). In the setting that both sides are harvested as DIEPs, the fascial should be closed primarily, and plication can correct any pre-existing diastasis and enhance the final abdominal contour (46). However, if more fascia is sacrificed or if a muscle-sparing transverse rectus abdominis myocutaneous (TRAM) was performed, the closure may require supplementation of mesh in order to prevent the risks of complications (1,44).
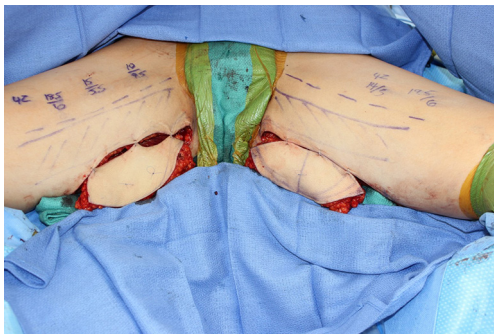
Figure 2 Bilateral PAP flap. PAP, profunda artery perforator.

Buttock

Historically, the gluteal region was the secondary donor site of choice for patients who were not candidates for autologous reconstruction from the abdomen (25,26). Most patients have sufficient soft tissue in the upper or lower buttock to provide ample volume for breast reconstruction (25,26). Both the superior and inferior gluteal arteries have reliable perforators that can supply a generous amount of volume for the SGAP and IGAP flaps respectively (25,47). The location of the perforators can be determined with the use of preoperative imaging, but the location of the main pedicle is well-defined based on anatomic landmarks (31,47,48). A hand-held Doppler can be utilized to confirm the location of perforators to design the flap (mm). Selecting a more lateral perforator is beneficial and will have a longer pedicle which will facilitate the microvascular anastomosis (31,47,48).

Despite the consistent anatomy and availability of tissue in the buttock, there are potential disadvantages that should be considered (47). The gluteal fat tends to have more firmness and is less pliable compared to the other donor sites (25). Another obvious disadvantage of performing either an IGAP or SGAP is the need for a position change unless a sloppy lateral position is used (25,49). While this can save ischemia time, it can be more challenging to perform the dissection for the less experienced surgeon, and generally, harvesting the flap in a prone position is preferred (25). The limited pedicle length, 5 to 8 cm for SGAP and 7 to 10 cm for IGAP, may require a vein graft for the anastomosis which adds another level of complexity for the reconstruction although certainly the anastomosis can be performed safely without the use of vein grafts (25,26,40,50). The intramuscular dissection of the pedicle, the increasing caliber of the vein, around 3 to 4 mm, and the multiple

side branches of the artery ("Medusa's head") beneath the gluteus maximus muscle, makes the flap elevation and pedicle anastomosis challenging (26,47,48,50). The closure of the donor site is generally well-tolerated but can result in contour deformities and gait disturbances which should be discussed with patients (25,50,51). In patients undergoing an IGAP flap, careful attention should be paid to avoid injury to the posterior femoral cutaneous nerve leading to numbness in the posterior thigh (49,51). If a sensate flap is required, inferior gluteal nerve branches (S1–S2) are preserved and elevated with the flap (25). Ideally, the scars should be concealed taking into account clothing including swimwear, but the scar for the SGAP can be visible, and the scar for the IGAP can migrate and lead to an unsightly scar that is not positioned in the intragluteal crease (25,51,52). The main goal should be a sensate flap because all women desire a functional reconstruction (mm). Considering this, the superior cluneal nerves can be harvested with the SGAP flap (25).

The increased flap loss rates of the gluteal region compared to the abdominal flaps are likely due to a combination of factors including a more challenging anastomosis, perhaps prolonged ischemia time with changes in patient positioning, and potentially traction on the perforators during the dissection for pedicle length (25,47,50).

Thigh

Given the increasing comfort with perforator flaps and understanding of anatomy, the medial thigh has largely replaced the buttock donor site as a secondary flap of choice for autologous breast reconstruction (27,28). The use of the medial thigh often avoids the need for position changes, and harvest of tissue from both thighs can typically provide ample volume for bilateral breast reconstruction in smaller-breasted patients, or can be combined to reconstruct a unilateral mastectomy defect (27,28,53). Alternatively, a thigh-based flap can also be combined with a DIEP flap for bilateral breast reconstruction if more volume is needed than can be provided from either donor site alone (27,53,54).

The two most commonly used flaps from the medial thigh are the TUG and PAP flaps, both of which have reliable anatomy and can be oriented transversely or longitudinally depending on the fat distribution in the medial thigh and patient acceptance of the resulting scar (*Figure 2*) (55,56). In general, a transversely oriented flap can yield a well-concealed scar but can have the risk of

Figure 3 PAP flap pedicle. PAP, profunda artery perforator.

migration and can also distort the vulva while a longitudinal scar can be more visible in clothing (55,57). The TUG incorporates the gracilis muscle and perfusion to the overlying skin is dependent on the presence of a perforator that does not need to be visualized during the dissection (56). The entire muscle is harvested with the flap, but the skin is most reliable proximally where the perforators arise through the bulk of the muscle (55,56). Care should be taken while dissecting the skin island anteriorly not to damage the lymph nodes (27). Furthermore, the cutaneous branches of the obturator nerve can be harvested for a sensate reconstructed breast (7). The vascular pedicle has a 6 to 8 cm length that is considerably shorter and smaller in caliber and can make the microsurgical anastomosis more challenging, often with a significant size mismatch with the internal mammary vessels (56). Although, by including the gracilis muscle, the flap can initially provide enough bulk but tends to shrink over time (56).

The PAP flap has grown noticeably in popularity for breast reconstruction when a DIEP flap cannot be performed or if additional volume is needed to supplement a DIEP flap (53,54,58,59). The flap can also be oriented differently, and the resultant scars are generally well-tolerated with limited donor site morbidity (*Figure 3*) (53,60). The dissection can be performed in the supine frog-leg position if the flap is harvested longitudinally, or in the lithotomy position if a transversely oriented flap is planned (53,60). Given the reliable perforators arising from the profunda femoris artery, we do not routinely obtain preoperative imaging unless a transversely oriented flap is harvested (53,59). In the setting that the proximal perforator is diminutive or if one is not present, a TUG can be performed if the patient is opposed to the lengthwise scar, or a vertical PAP if the patient is willing to tolerate the scar (60). The pedicle is usually of adequate length, approximately 10 cm, but the caliber of

the artery can be smaller than the internal mammary artery (53,58,59). In order to avoid a drastic size mismatch that can lead to turbulent flow, the internal mammary vessels can be dissected more distally, or an internal mammary perforator can be used as well (53). The flap can be raised with posterior femoral cutaneous nerve for improved sensitivity (7).

Anteriorly introduced as septocutaneous tensor fasciae latae (sc-TFL) flap, the newly described LTP flap is based on the septocunateous perforator located between the TFL and the gluteus minimus/medius muscles and originating from the ascending branch of the lateral circumflex femoral artery (LCFA) (29,61). The main advantages of this flap are the fact that usually the lateral thigh region has sufficient fat volume, the flap can be harvested in a supine position, avoiding prolonged ischemia time and the dissection is straightforward, with a consistent and reliable pedicle (61,62). Perforators are located on the horizontal line drawn from the pubic bone that perpendicularly crosses the line from the anterior superior iliac spine (ASIS) to the lateral border of the patella (29). The most cranially and sizeable located perforators should be selected in an attempt to hide the scar in the underwear (29). Unless a sensate reconstruction is wanted, care should be taken to avoid the lateral femoral cutaneous nerve. Flap dissection is made in a suprafascial manner with a 6 to 8 cm pedicle length (29). Refinements have been done over the last years to minimize the donor site morbidity by limiting the flap width, using quilting sutures for closure and improving thigh contour with lipofilling and liposuction (29,62). The LTP flap is an emerging alternative option in breast reconstruction, offering an advantageous pliable tissue with good projection that provides a good aesthetic result (62).

Lumbar

The LAP flap is based on perforators arising at the 3rd or 4th lumbar vertebrae (63-65). While a handheld Doppler can be used reliably to localize the perforators, preoperative imaging may also be useful in helping the microsurgeon design the flap (64-66). Even lean patients do have excess tissue in the lumbar area, and the resulting contour is also quite favorable (67). However, the flap harvest is typically done prone so most microsurgeons using the LAP flap actually have two position changes during surgery (67).

While the consistency of the tissue nicely mimic the abdominal and breast tissue, the pedicle is often considerably shorter, of approximately 6 cm, and many

recommend the use of grafts to perform the anastomosis (63,64,67). In fact, many will harvest the deep inferior epigastric vessels in order to lengthen the pedicle (66,67). The dissection becomes quite tedious in order to gain additional length (63). At the transverse process' region the dissection stops, and clips are avoided after 4 cm pedicle length due to the high risk of nerve roots damage (67). Also, incorporating the superior cluneal nerves to be anastomosed to the intercostal nerves, can make a sensate reconstruction possible (7,66). Lately, the donor area morbidity was significantly decreased with minimal undermining, avoiding overharvesting lumbar tissue, using quilting sutures and vest-over-pants closure of the donor site (64,67).

Early reports using the LAP flap for breast reconstruction have demonstrated high complications and flap loss rates compared to abdominal flaps which may simply be attributed to the learning curve (63,67). Although the cone shape design and the upper pole fullness are important advantages, given the need for vessel grafts, additional position changes, and potential higher risks of flap failure, the LAP flap is a secondary option for autologous breast reconstruction, and serious considerations and discussion with the patient are necessary before committing to this option (64,67).

Monitoring and recovery

While post-operative monitoring and management vary tremendously based on surgeon preference and hospital resources, the majority of thrombotic events tend to occur with the first 24–72 hours following surgery (11). During this time, it is imperative to detect compromised perfusion as early as possible and return to the operating room as expeditiously as possible to maximize the success of flap salvage (11,68-70). Early reports with implantable Dopplers, tissue perfusion monitors, and oxygen saturation monitors have demonstrated promising results, but none supplant the gold standard method—clinical experience, exam, and judgment (68-72). If there is any suspicion for a thrombosis, it is far preferable to have a negative exploration than a total flap loss (68).

All patients, particularly obese patients, should be promptly started on venous thromboembolic event (VTE) prophylaxis; however, whether patients should receive additional anticoagulation is at the surgeon's discretion (11). Most studies have not demonstrated any protective or preventive benefit using heparin, dextran, or aspirin, although the risks of hematoma are increased (11). For most patients,

recovery from the operation is approximately 2–3 months, predominantly due to decreased stamina and energy rather than actual wound healing or pain management (73). With the growing popularity and implementation of enhanced recovery after surgery (ERAS) protocols, pain management has trended away from opioid reliant medications, and more to multi-modality therapy with the aim of decreasing narcotic use and hospital length of stay (73).

Conclusions

While the DIEP flap remains the gold standard of autologous breast reconstruction, in cases without abdominal tissue available, the alternative methods of autologous reconstruction provide good quality tissue coverage. With the description of more donor site options, increased comfort and training with microvascular surgery and perforator flaps, introduction of new technology for flap monitoring, and expanding indications, nearly all patients are candidates for autologous reconstruction.

Considering the reviewed literature data, we believe that we managed to collect enough information to provide an objective and comprehensive review article in order to help plastic surgeons in following a thorough algorithm for choosing the best nonabdominally-based breast reconstructive method, given the particularity of each patient, when the DIEP flap is not available. Given our findings, we think that further research is needed.

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Footnote

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