OPEN

Clover-Style Fasciocutaneous Perforator Flap for Reconstruction of Massive Sacral Pressure Sores

Jian Cheng, MD,[a,b] Qi Zhang, MD,[b,c] Shiming Feng, MD,[a] Xiaodong Wu, MD,[a] Weiling Huo, BS,[a] Yong Ma, PhD,[b] Jianping Cai, PhD,[b] and Mingming Liu, MD[d]

Background: As a common complication of the long-term bedridden patients, pressure sore is a great challenge for surgeons. The purpose of this study was to explore the surgical method of using a clover-style fasciocutaneous perforator flap raised on the buttocks for the treatment of massive sacral pressure sores and report the clinical outcomes.

Methods: The study included 15 patients from January 2015 to June 2017 with an average age of 52.87 years (range, 32–73 years). The size of the sacral pressure sores ranged from 10 cm × 13 cm to 18 cm × 20 cm. The defects were reconstructed using a fasciocutaneous perforator flap raised on the buttocks after debridement and vacuum sealing drainage treatment for 1 to 2 weeks. All the donor areas were sutured directly.

Results: All flaps survived completely; 13 patients achieved healing by primary intention, and the other 2 patients achieved healing by secondary intention. At the mean follow-up period of 20.8 months (range, 12–46 months), the appearance of the flap, including its texture and color, in all patients was satisfactory. No patients had deep infection, necrosis, or shrinkage of the flap during the follow-up period. One patient had a recurrent bedsore during the 2-year follow-up.

Conclusions: The clover-style fasciocutaneous perforator flap is ideal for the reconstruction of massive sacral pressure sores because it is a relatively simple procedure and results in good appearance and function, few complications, and a low recurrence rate.

Key Words: sacral pressure sores, fasciocutaneous flap, perforator flap, reconstruction

(*Ann Plast Surg* 2021;86: 62–66)

Pressure sores are a common complication of long-term bedridden patients; they are also observed among patients with spinal cord injury, cerebrovascular accident, hip fracture, and advanced tumors. Pressure sores are mainly caused by long-term compression, tissue ischemia, and hypoxia. Infection, friction, and malnutrition are also important factors for the aggravation of bedsores.[1,2] Currently, gluteus maximus myocutaneous flaps are mainly used for the surgical repair of sacral bedsores.[3,4] These flaps have advantages of good blood supply and strong anti-infection ability, but they also have shortcomings, such as bloated appearance, limited donor areas, and impairment of gluteus maximus function.[5,6]

A perforator vascular flap raised on the buttocks was first reported by Koshima et al[7] in 1993, and it addressed the deficiencies of gluteus maximus myocutaneous flaps. Currently, the perforator vascular flap is increasingly being used to repair sacral wounds[8,9]; however, the operation is complicated, and it is still difficult to repair large bedsores. We have modified the perforator vascular flap and designed the clover-style fasciocutaneous perforator flap for the repair of massive sacral pressure sores. Here, we report our experience of the successful reconstruction of sacral pressure sores using this modified flap technique.

PATIENTS AND METHODS

General Information

We retrospectively reviewed 15 patients with massive sacral pressure sores who underwent reconstruction with a clover-style fasciocutaneous perforator flap from January 2015 to June 2017. The patients included 8 men and 7 women, and their mean age was 52.87 years (range, 32–73 years). There were 10 cases of spinal cord injury with paraplegia, 3 cases of severe craniocerebral trauma, 1 case of hip fracture, and 1 case of multiple fractures. All patients had a long history of bed rest. According to Shea classification,[10] there were 10 cases of grade III sores and 5 cases of grade IV sores. The sizes of the sacral defects ranged from 10 cm × 13 cm to 18 cm × 20 cm (mean, 13.13 cm × 16.73 cm). Most of the patients had soft tissue or bone infections with deep wounds. In addition, the areas of the wounds after debridement ranged from 11 cm × 14 cm to 20 cm × 23 cm (mean, 14.86 cm × 18.33 cm). The flap size ranged from 12 cm × 15 cm to 22 cm × 24 cm (mean, 16.0 cm × 19.87 cm). Detailed patient factor information can be found in Table 1. All patients with sacral sores were transferred from other departments to our department, and pressure sores were treated by a dressing change in the original department; however, the results were poor. The research conducted in human subjects complied with the ethical rules for human experimentation, and approval was obtained by the research ethics board of Xuzhou Central Hospital. All patients or their legal guardians had given their written informed consent for patient information and images to be published.

Preoperative Preparation

After admission, all patients underwent bacterial culture of wound secretions and drug sensitivity detection before operation. Paraplegic patients were catheterized to keep the perineum clean. Sensitive antibiotics were prescribed according to the results of the bacterial culture of secretions. Patients maintained the prone position; however, if that position was difficult for some patients, they could maintain the lateral position.

Debridement

Necrotic and scar tissues were debrided as completely as possible during the operation; in addition, any bone tissue in the sacral wound was removed if it would impede coverage by the flap. Vacuum sealing drainage (VSD) was applied to the wounds after debridement in all patients for 1 week. If the wounds still had abundant secretions

Received January 13, 2020, and accepted for publication, after revision April 23, 2020.
From the [a]Department of Orthopedics, Xuzhou Central Hospital; [b]Graduate School, Nanjing University of Chinese Medicine, Nanjing; [c]Department of Oncology, Xuzhou TCM Hospital Affiliated to Nanjing University of Chinese Medicine, Xuzhou, Jiangsu; and [d]Department of Orthopedics, The Second People's Hospital of Lianyungang, Lianyungang, Jiangsu, China.

J.C. and Q.Z. equally contributed to this work.
Conflicts of interest and sources of funding: none declared.
Reprints: Mingming Liu, MD, Department of Orthopedics, The Second People's Hospital of Lianyungang, No. 161, Xingfu South Rd, Haizhou District, Lianyungang, Jiangsu, China. E-mail: drorthop@126.com.

ISSN: 0148-7043/21/8601–0062
DOI: 10.1097/SAP.0000000000002442

TABLE 1. General Information of Patients

Case	Age, y	Sex	Primary Diseases	Shea Classification	Defect Size, cm × cm	Flap Size, cm × cm	Pedicle Length, cm
1	32	Male	C5/6 spinal cord injury with paraplegia	III	10 × 14	12 × 15	2.5
2	37	Male	C4/5 spinal cord injury with paraplegia	IV	18 × 20	22 × 24 (12 × 24 + 10 × 24)	3.5/4.0
3	53	Male	Fracture of bilateral femurs and the second lumbar vertebrae	III	12 × 16	15 × 18 (8 × 15 + 10 × 15)	2.5/3.5
4	66	Female	Severe craniocerebral trauma	IV	15 × 18	18 × 22 (8 × 22 + 10 × 22)	3.0/3.5
5	56	Female	C6/7 spinal cord injury with paraplegia	III	12 × 15	15 × 18 (8 × 15 + 10 × 15)	2.0/3.0
6	62	Male	Severe craniocerebral trauma	III	10 × 14	12 × 16	3.0
7	45	Female	C7/T1 spinal cord injury with paraplegia	III	15 × 16	18 × 20 (8 × 20 + 10 × 20)	3.5/3.5
8	73	Female	Fracture of right femoral neck	III	12 × 18	15 × 22 (10 × 15 + 12 × 15)	2.5/3.0
9	43	Male	T3/4 spinal cord injury with paraplegia	III	10 × 15	14 × 18 (8 × 14 + 10 × 14)	2.0/2.5
10	58	Female	C6/7 spinal cord injury with paraplegia	IV	16 × 20	20 × 24 (12 × 20 + 12 × 20)	3.0/4.5
11	65	Male	C5/6 spinal cord injury with paraplegia	III	10 × 13	12 × 15	2.5
12	49	Male	T1/2 spinal cord injury with paraplegia	III	15 × 20	18 × 24 (10 × 18 + 14 × 18)	2.5/4.0
13	36	Male	Severe craniocerebral trauma	IV	16 × 18	18 × 22 (10 × 18 + 12 × 18)	3.0/3.0
14	53	Female	C5/6 spinal cord injury with paraplegia	IV	12 × 18	15 × 20 (10 × 15 + 10 × 15)	2.5/3.0
15	65	Female	C4/5 spinal cord injury with paraplegia	III	14 × 16	16 × 20 (8 × 20 + 8 × 20)	3.0/3.5
Mean	52.87				13.13 × 16.73	16.0 × 19.87	3.04

Demographics and clinical characteristics of the patients enrolled in the research.
C, cervical vertebra; T, thoracic vertebra.

after 1 week, they were treated with debridement and VSD again. The flap repair was performed when the wound tissue was fresh and the amount of secretion was low.

Surgical Procedure

Design of Flap

As is well known, the fasciocutaneous perforator vessels of the superior gluteal artery and the inferior gluteal artery are the main nutrient vessels of the sacrococcygeal skin, which is the basis of our flap design. Point A was set at the junction of the medial one third and lateral two thirds of the line drawn between the posterior-superior iliac spine (PSIS) and the apex of the greater trochanter of the femur (GTF), and this was the projection of the superficial branch of the superior gluteal artery on the body surface. Point B was set at the junction of the midpoint of the line between the PSIS and the ischial tuberosity (IT), and this was the projection of the muscular branch of the inferior gluteal artery on the body surface.[11] The clover-style fasciocutaneous perforator flap from 1 or 2 sides of the buttocks was designed according to the size of the sacral pressure sores (Fig. 1). The inferior lobe was the main lobe, and the range of the inferior lobe was designed according to the size of the wound. The distance measured between the pedicle and the furthest end of the wound was the same as that between the pedicle and the distal end of the inferior lobe. The skin of the main lobe of the donor flap was pinched to simulate the tension of the donor area when the donor flap was cut and sutured directly. The size of the defect area that may appear in the proximal side was marked, and the shape of the lateral lobe was determined according to the size of the defect area. It was important that the edge of the lateral lobe did not exceed the front edge of the great trochanter of the femur. The shape of the upper lobe was determined according to the size of the lateral lobe. The flap and the pedicle were drawn on the body surface with methylene blue. The flap was simulated by gauze to determine whether the flap design was appropriate and was later rotated to cover the defect.

Flap Section

The full-thickness skin of the flap was cut vertically along the outer edge of the marking line to the deep fascia layer. First, the flaps of the upper and lateral lobes were separated by clinging to the deep fascia layer; at this point, the doctors carefully located perforator vessels (superior or inferior gluteal artery and its communicating branch) while

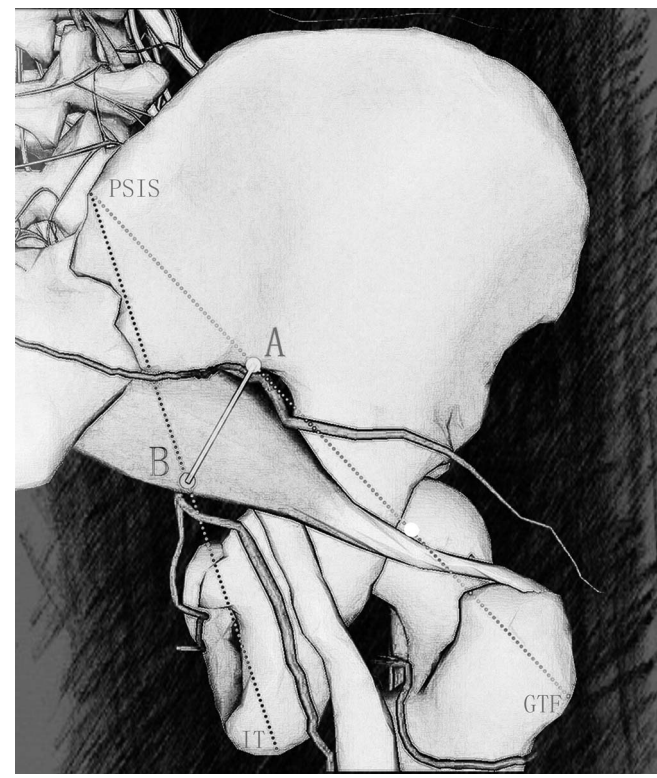

FIGURE 1. Point A was set at the junction of the medial one third and lateral two thirds of the line drawn between the PSIS and the apex of the GTF, and point B was set at the junction of the midpoint of the line between the PSIS and the IT.

separating the flaps. The flap of the inferior lobe was separated after the main perforating vessel was separated. Finally, the clover-style fasciocutaneous perforator flap was rotated clockwise or counterclockwise. The skin around the inferior lobe flap was properly separated, the distal skin was directly sutured, and the triangular defect at the proximal end was covered by the lateral lobe. The larger perforating branch between the superior and inferior gluteal vessels was preferred as the flap pedicle. The perforating branch close to the main lobe should be selected as the flap pedicle to ensure the flap supplement in the case that no sizable perforating branch was observed. An approximately 3 cm × 3 cm muscle cuff was preserved with the pedicle for flap. Preservation of some gluteus maximus tissue around the pedicle is critical for flap survival. Details regarding flap size and pedicle length can be found in Table 1. The color of the flap was observed during the operation to ensure that the blood supply was not injured. Whole-layer sutures were used on the skin, and a negative-pressure drainage tube was placed under the flap after the operation.

Postoperative Management

Sensitive antibiotics were used postoperatively. For the first 2 weeks, the patients were placed in the prone position until the stitches were removed. Partial pressure was indicated on the site of the flap coverage in the following 2 weeks. The patients were not allowed to lie or sit on their buttocks for 4 weeks after surgery. The flap was closely monitored to ensure adequate blood supply and optimal tension of the flap; moreover, the partial sutures were removed intermittently if the tension was high. If the patient had flexion contracture of the hip, muscle relaxants could be taken orally. To prevent poor wound healing caused by blood stasis under the flap, the drainage tube was removed when less than 5 mL of drainage fluid was detected in 24 hours.

RESULTS

The donor and recipient sites of 15 patients were closed in a 1-stage procedure without skin grafting; bilateral clover-style perforator flaps were used in 12 patients, and unilateral perforator flaps were used in 3 patients. The negative-pressure drainage tubes were removed 3 to 7 days (mean, 5.2 days) postoperatively. In 2 patients, venous congestion was observed in the flap after the operation but did not affect flap survival. All the flaps survived, and 13 patients achieved healing by primary intention, whereas the other 2 patients healed by secondary intention. There was minor exudation from the incision of 1 patient when the sutures were removed on the 14th day after surgery, and the exudate was primrose yellow. However, the inflammatory index in the blood examination of the patient was not high, whereas the plasma albumin was low, and the patient was treated with intravenous albumin. Finally, the wound healed after 1 week of daily dressing changes. Another patient with diabetes mellitus experienced partial wound dehiscence on the sixth day after surgery. The patient's incision was close to the anus and susceptible to contamination; meanwhile, his blood glucose was higher postoperatively. The patient received hypoglycemic treatment by injecting insulin, whereas the intake of a crude fiber diet was controlled to reduce fecal pollution of the wound. The wound healed after 23 days of dressing changes. All patients were followed up once every 3 months, and the mean follow-up period was 20.8 months (range, 12–46 months). The overall appearance of the flaps was satisfactory, and the texture and color of the flaps were good in all patients. No patients had deep infection, necrosis, or shrinkage of the flap during the follow-up period. One patient had recurrent bedsore (grade II) during the 2-year follow-up, with an area of 2 cm × 3 cm, which healed after dressing changes. Skin sensation was partially recovered at the donor sites of 2 patients with fracture. Although slight numbness remained, it did not interfere with the patients' daily lives. In the remaining 13 patients, the skin of the buttocks had sensory disturbance before the operation due to the original diseases, such as spinal cord injury accompanied by paraplegia, and there was still a lack of sensation in the skin after the operation. One of the patients with cervical spinal cord injury accompanied by high paraplegia died of pulmonary infection during the one-year follow-up.

FIGURE 2. A, Preoperative appearance of the sacral pressure sore. B, Clover-style fasciocutaneous perforator flap for wound repair during the operation. C, The recipient and donor sites were closed in a 1-stage procedure, and a drainage tube was placed under the flap. D, The flap survived well after the 3-year follow-up, the appearance of the buttocks was satisfactory, and there was no recurrence of the bedsore. full color online

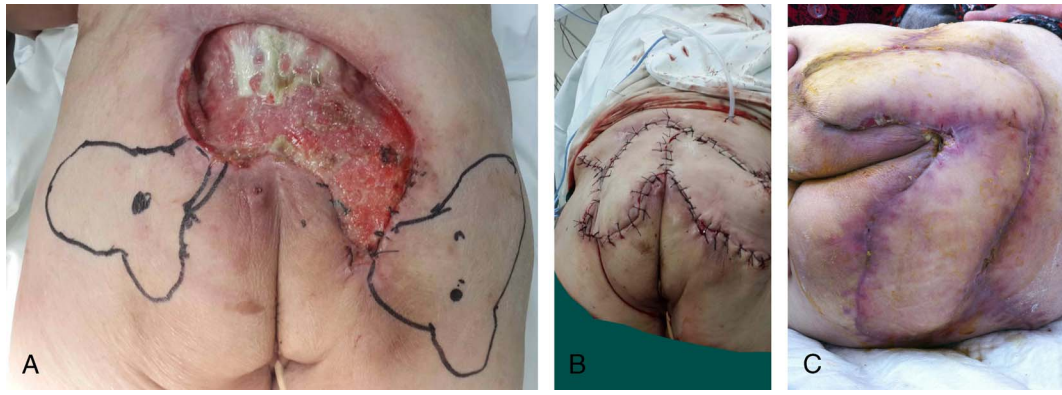

FIGURE 3. A, Preoperative appearance of the sacral pressure sore and design of clover-style musculocutaneous perforator flap. B, The recipient and donor sites were closed in a 1-stage procedure, and the tension of the flap was lower. C, Partial incision near the anus dehisced and had exudate postoperatively, and this wound healed after dressing changes. full color online

Case Report 1

A 37-year-old man acquired a 4/5 cervical fracture and dislocation accompanied by quadriplegia after being struck by a motorcycle. The patient did not experience sensation and was incapable of movement below the nipple level. Because he was bedridden, an extensive grade IV pressure sore was noted on his sacral region, and the wound was approximately 18 cm × 20 cm. A bilateral clover-style fasciocutaneous perforator flap was designed to repair the wound. The size of the left flap was approximately 10 cm × 24 cm, and that of the right flap was approximately 12 cm × 24 cm. Necrotic tissue was thoroughly debrided at the first stage of the operation, and continuous VSD was applied on the wound for 1 week postoperatively. The granulation tissue of the wound was redder, and there was less exudate after removing the VSD; then, the second stage of the operation was performed to transpose the clover-style perforator flap. The flap survived well, and the sutures were removed 2 weeks after the operation. During the 3-year follow-up, the pressure sore did not recur, and the appearance of the buttocks was symmetrical; moreover, the patient was satisfied (Fig. 2).

Case Report 2

A 73-year-old woman with a history of diabetes acquired a fracture of the right femoral neck after a tumble. She was treated with closed reduction and cannulated-screw internal fixation. Because she was bedridden, a grade III pressure sore was noted on her sacral region, and the wound was approximately 12 cm × 18 cm. A bilateral fasciocutaneous perforator flap was designed to repair the wound. The size of the left flap was approximately 12 cm × 15 cm, and that of the right flap was approximately 10 cm × 15 cm. The flap survived after surgery, but partial incision near the anus dehisced on the sixth day postoperatively, and this wound healed after 23 days of dressing changes. During the follow-up, the pressure sore did not recur, and the appearance of the buttocks was satisfactory; skin sensation was partially recovered at the donor sites, but slight numbness remained (Fig. 3).

DISCUSSION

Anatomical Basis of the Clover-Style Fasciocutaneous Perforator Flap

The blood supply of the flap raised on the buttocks is mainly from the posterior branch of the fourth lumbar artery, superior gluteal artery, and inferior gluteal artery, most of which are fasciocutaneous perforators, and these perforating branches are anastomosed with each other.[11–13] The anatomy of the perforating branches of the superior gluteal artery and inferior gluteal artery is relatively confirmed. The superficial sign of the superior gluteal artery is the junction of the medial one third and lateral two thirds of the line drawn between the PSIS and the apex of the GTF, and the superficial sign of the inferior gluteal artery is the junction of the midpoint of the line between the PSIS and IT.[11,14] In addition, the 2 perforating branches have communicating branches in the deep fascia. Previous anatomical studies have shown that the average diameter of the perforating vessels is greater than 1 mm.[7,15] In addition, the perforating vessels are widely distributed, the area of a single perforating branch is relatively confirmed, and the blood supply is reliable.[13,15] According to an anatomical study by Ahmadzadeh et al[14] and Hu et al,[16] the average diameters of the perforating vessels of the superior and inferior gluteal arteries were both 0.6 ± 0.1 mm, and the number of perforating vessels was 5 ± 2 and 8 ± 4, respectively. The average area that the superior and inferior gluteal vessels covered was 69 ± 56 cm^2 and 177 ± 38 cm^2, respectively, and the blood supply area of each perforating artery was 21 ± 8 cm^2 and 24 ± 13 m^2, respectively. Lui et al[17] reported the anatomy of the superior gluteal artery by 3-dimensional computed tomography angiography and found similar anatomical results. The fixed anatomical marks of the perforating arteries in the buttocks and the low variation, convenient location, and abundance of the blood supply provide the anatomical basis for the wide clinical application of the fasciocutaneous perforator flap.

Operative Notes

The pedicle should be dissected gradually from the circumference of the flap to the marked pedicle along the deep fascia layer. Typically, the perforating branch of the superior gluteal artery is used as the pedicle, as the route of the perforating branch of the inferior gluteal artery is more variable than that of the superior gluteal artery.[13,18] Meanwhile, if after the main lobe was dissected and multiple perforating branches affected the rotation of the flap, the perforator vessel closest to the central part of the flap should be chosen as the pedicle. Otherwise, the twisting of the perforating branches in the flap after rotation will affect the venous return and even the arterial blood supply. In addition, as the flap may contract after its removal, the length and width of the inferior lobe should be approximately 1 cm larger than those of the wound to reduce tension after suturing.

Characteristics, Advantages, and Disadvantages of the Clover-Style Fasciocutaneous Perforator Flap

There are many options for the coverage of sacral pressure sores. Fasciocutaneous flaps with gluteal rotation can provide good blood supply and an adequate amount of soft tissue for the defect.[19] However, because of the insufficient length of the pedicle and the limited donor

areas, there are some limitations in the design of the flap. The keystone island flap is a multiperforator advancement flap originally described and classified in 2003 by Behan et al.[20] Because keystone flaps can decrease technical difficulty and provide relatively pain-free recovery and early mobilization, the keystone flap procedure should be an ideal procedure for reconstruction for wound closure.[21] However, the keystone flap acts as an advancement flap that requires local tissue laxity for advancement, while there is insufficient local tissue laxity of the lumbosacral area. The multi-island flap design can reduce the tension of the donor area in the design of various types of flaps.[22,23] Therefore, we improved the fasciocutaneous perforator flap on the basis of the superior gluteal artery perforator flap. We considered the projection area of the superficial branch of the superior gluteal artery or the muscular branch of the inferior gluteal artery as the center and selected the dominant perforating branch as the pedicle. Compared with the superior gluteal artery perforator flap, the clover-style fasciocutaneous perforator flap allowed the use of the perforating branch of the superior gluteal artery, the inferior gluteal artery, or their communicating branch as the pedicle. Therefore, a wider range of pedicles could be used for the clover-style fasciocutaneous perforator flap, and the design of the flap is flexible. Because of the auxiliary actions of the upper and lateral lobes, the shape of the flap was full and smooth after the whole flap was rotated to cover the defect area. The tension of the direct suture in the inferior lobe was often concentrated in the triangular region at the proximal end of the flap, but the addition of the lateral lobe dissolved the tension in the suture and was beneficial for the healing of the incision and the reduction of scar formation. Therefore, the design of the clover-style flap reduced the distortion and tension of the wound. Compared with the classical musculocutaneous flaps with the gluteus maximus muscle, the clover-style fasciocutaneous perforator flap did not damage the gluteus maximus muscles and did not affect hip extension function or the walking gait of the lower limbs among nonparaplegic patients. Moreover, the cutting range of this flap was larger than that of the gluteus maximus myocutaneous flap. Of note, because the cutaneous nerve was transected during the operation, there was numbness and discomfort at the donor sites of nonparaplegic patients after the operation. In the future, we will try to perform cutaneous nerve anastomosis in nonparaplegic patients.

Indications and Contraindications

In this study, the clover-style fasciocutaneous perforator flap was applied to repair sacral pressure sores with satisfactory clinical results. This flap is suitable for patients with sacral defects caused by long-term bed rest, infection, and trauma, especially large and refractory bedsores in the buttocks. However, the flap should not be used in patients with an injured perforating artery of the buttocks. For patients with suspected perforating vessel injury, Doppler ultrasonography or 3-dimensional computed tomography angiography can be used to exclude vascular lesions.[17,24] If conditions are suitable, Doppler ultrasound can be routinely used to detect and mark large perforating vessels before operation to facilitate the preservation of perforator pedicles during the operation.

CONCLUSIONS

The clover-style fasciocutaneous perforator flap is easy to create and eliminates the need for microsurgery. Moreover, the flap has advantages, including an enhanced blood supply, a high survival rate, a flat appearance, and a low bedsore recurrence rate. In conclusion, this surgical technique yields good clinical results and is worth popularizing.

ACKNOWLEDGMENT

The authors thank Huanhuan Feng, MD (from the Affiliated Taicang Hospital of Nanjing University of Chinese Medicine, Jiangsu, China), for help with the figure editing.

REFERENCES

1. Rieger U, Scheufler O, Schmid D, et al. Six treatment principles of the basle pressure sore concept. *Handchir Mikrochir Plast Chir*. 2007;39:206–214.
2. Wettstein R, Tremp M, Baumberger M, et al. Local flap therapy for the treatment of pressure sore wounds. *Int Wound J*. 2015;12:572–576.
3. Mett TR, Boyce MK, Ipaktchi R, et al. Defect coverage using gluteal flaps. *Oper Orthop Traumatol*. 2018;30:236–244.
4. Chen YC, Huang EY, Lin PY. Comparison of gluteal perforator flaps and gluteal fasciocutaneous rotation flaps for reconstruction of sacral pressure sores. *J Plast Reconstr Aesthet Surg*. 2014;67:377–382.
5. Lefèvre C, Bellier-Waast F, Lejeune F, et al. Ten years of myocutaneous flaps for pressure ulcers in patients with spinal lesions: analysis of complications in the framework of a specialised medical-surgical pathway. *J Plast Reconstr Aesthet Surg*. 2018;71:1652–1663.
6. Yang CH, Kuo YR, Jeng SF, et al. An ideal method for pressure sore reconstruction: a freestyle perforator-based flap. *Ann Plast Surg*. 2011;66:179–184.
7. Koshima I, Moriguchi T, Soeda S, et al. The gluteal perforator-based flap for repair of sacral pressure sores. *Plast Reconstr Surg*. 1993;91:678–683.
8. Chen W, Jiang B, Zhao J, et al. The superior gluteal artery perforator flap for reconstruction of sacral sores. *Saudi Med J*. 2016;37:1140–1143.
9. Chang CK, Wu CJ, Chen CY, et al. Intraoperative indocyanine green fluorescent angiography-assisted modified superior gluteal artery perforator flap for reconstruction of sacral pressure sores. *Int Wound J*. 2017;14:1170–1174.
10. Shea JD. Pressure sores: classification and management. *Clin Orthop*. 1975;112:89–100.
11. Song WC, Bae SM, Han SH, et al. Anatomical and radiological study of the superior and inferior gluteal arteries in the gluteus maximus muscle for musculocutaneous flap in Koreans. *J Plast Recons Aesthet Surg*. 2006;59:935–941.
12. Georgantopoulou A, Papadodima S, Vlachodimitropoulos D, et al. The microvascular anatomy of superior and inferior gluteal artery perforator (SGAP and IGAP) flaps: a fresh cadaveric study and clinical implications. *Aesthetic Plast Surg*. 2014;38:1156–1163.
13. Mu LH, Yan YP, Luan J, et al. Anatomy study of superior and inferior gluteal artery perforator flap. *Zhonghua Zheng Xing Wai Ke Za Zhi*. 2005;21:278–280.
14. Ahmadzadeh R, Bergeron L, Tang M, et al. The superior and inferior gluteal artery perforator flaps. *Plast Reconstr Surg*. 2007;120:1551–1556.
15. Kankaya Y, Ulusoy MG, Oruc M, et al. Perforating arteries of the gluteal region: anatomic study. *Ann Plast Surg*. 2006;56:409–412.
16. Hu SW, Dai KN, Mei J, et al. Applied anatomy of the superior and inferior gluteal artery perforator flaps. *Chin J Clin Anat*. 2006;24:243–246.
17. Lui KW, Hu S, Ahmad N, et al. Three-dimensional angiography of the superior gluteal artery and lumbar artery perforator flap. *Plast Reconstr Surg*. 2009;123:79–86.
18. Zhang JL, Liu LG, Wu YJ. Anatomic observation of inferior gluteal artery. *Zhonghua Zheng Xing Wai Ke Za Zhi*. 2005;21:44–46.
19. Han HH, Choi EJ, Moon SH, et al. Combined V-Y fasciocutaneous advancement and gluteus maximus muscle rotational flaps for treating sacral sores. *Biomed Res Int*. 2016;2016:8714713.
20. Behan FC. The keystone design Perforator Island flap in reconstructive surgery. *ANZ J Surg*. 2003;73:112–120.
21. Mohan AT, Rammos CK, Akhavan AA, et al. Evolving concepts of keystone perforator island flaps (KPIF): principles of perforator anatomy, design modifications, and extended clinical applications. *Plast Reconstr Surg*. 2016;137:1909–1920.
22. Xu Y, Hai H, Liang Z, et al. Pedicled fasciocutaneous flap of multi-island design for large sacral defects. *Clin Orthop Relat Res*. 2009;467:2135–2141.
23. Wu ZX, Wei P, Liang J, et al. Reconstruction of sacrococcygeal bedsore by transposition of bilobar fasciocutaneous flap with nutrient vessels of gluteal epithelial nerve. *Chin J Microsurg*. 2013;36:302–304.
24. Long TF, Zhang XX, Zhao H, et al. Anatomy of the superior gluteal artery assessed by three-dimensional computed tomographic angiography. *Chin J Clin Anat*. 2013;31:402–406.