INTRODUCTION

Medial lumbar and lumbosacral defects are a relatively common problem in reconstructive surgery but remain difficult to manage because few local coverage solutions exist. In recent years, the advent of perforator flaps has allowed us to respond to defects that are often very complex in terms of coverage. Using lumbar perforating arteries, lumbar artery perforator flaps (LAPs) can be performed in such clinical contexts.

LAPs were first described by Kroll and Rosenfield1 in 1988 as a new type of perforator flap, based on perforators that had not yet been named. Since then, several studies have highlighted the possible use of LAPs in their pedicled form to cover lumbosacral defects,2–5 but also as free flaps, mainly in autologous breast reconstruction where other solutions are not possible, particularly at abdominal or gluteal donor sites.6,7

Recent cadaveric and radio-anatomical studies have specifically studied lumbar perforating arteries.8–11 Average pedicle diameters, their locations in relation to the median line and the bone prominences, and their musculocutaneous or septocutaneous courses are now better known for the first 4 pairs of lumbar arteries.11 Clusters have been defined, making it possible to identify the statistically preferential locations of potential perforators.10,12 According to Lui et al., LAPs allow harvesting a related digital media available in the full-text version of the article on www.PRSGlobalOpen.com.

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large volume of tissue, with a theoretical average perfora-
some\(^{13}\) of 30 cm\(^2\) (range 14–64).

We report here a multicenter study on LAPs per-
formed to treat lumbar defects of various etiologies. Our
goal was to highlight the versatility of this flap as well as its
robustness and reproducibility using a surgical procedure
that allows the flap to be harvested with minimum risk.

### METHODS

Thirty-one patients were operated on between
November 2012 and March 2019 at Toulouse and
Strasbourg University hospitals. The same procedure was
taught by the senior author (BC) to all teams. For 29 of
the patients, 1 LAP was sufficient to cover the defect; for
2 patients, we combined LAP with another flap (a sec-
ond LAP and 2 superior gluteal artery perforator flaps
[S-GAPs]). Indications were diverse: neurosurgical comp-
lications, extensive burns, oncodermatology, and ballis-
tic injury. Table 1 summarizes all the data in this series.

All perforator arteries were identified preoperatively
using an acoustic handheld Doppler (HADECO Bidop
ES-100 8 MHz). Color Doppler identification was also per-
formed where there was any doubt about the perforator
path. Surgery performed under general anesthesia, with
patients in prone position. All procedures were accompa-
nied by antibiotic prophylaxis and secondarily targeted
antibiotics based on previous microbiology samples.

After locating the pertinent perforating artery, then
tracing the contours of the skin paddle dermographic
pen, the flap was raised in a suprafascial plane, laterally to
medially. (See Video [online], which shows the harvest of
a LAP with a skin paddle of 16 cm × 7 cm, on the right side,
which was turned with an arc of rotation of 100 degrees,
with a suprafascial dissection, and a single lumbar perfo-
rator pedicle.) Once the perforator pedicle was identified
and isolated, depending on the arc of rotation and cuta-
neous constraints, the perforator was more or less skele-
tonized. The flap was then turned and sutured without
tension and with appropriate drainage. The donor site,
always primarily closed, was also sutured with appropriate
drainage.

#### Case No. 1 (Number 6 in Table 1) (Fig. 1)

A 35-year-old man received a gunshot to the spine
next to L1, causing flaccid paraplegia. The mixed ballistic
mechanism, combining contusion and burn, did not allow
healing even after 2 months of negative pressure wound
therapy (NPWT). A pressure sore persisted for more than

### Table 1. Data Summary

| Patient | Age | Sex | Comorbidity | Osteosynthesis | NPWT before Surgery | Etiology of Defect | Defect Localization | Defect (cm) |
|---------|-----|-----|-------------|----------------|---------------------|-------------------|--------------------|------------|
| 1       | 58  | M   | Diabetes    | No             | 4 wk Laminectomy   | I2–L4             | 5 × 5              |
| 2       | 46  | M   | No          | No             | 4 wk Melanoma      | I2–L3             | 7 × 4              |
| 3       | 60  | M   | Radiotherapy| No             | No Sarcoma         | L3–L5             | 10 × 7             |
| 4       | 40  | M   | Schizophrenia| No             | 2 wk Burns         | T12–L5            | 24 × 7             |
| 5       | 63  | F   | Radiotherapy| No             | 2 wk Sacral chordoma| L3–S1             | 8 × 5              |
| 6       | 35  | M   | No          | Spinal osteosynthesis | 4 wk Ballistic injury | L1–L2             | 3 × 3              |
| 7       | 69  | M   | No          | No             | 3 wk Melanoma      | L1–L2             | 6 × 4              |
| 8       | 73  | F   | Diabetes    | No             | L3 Spondylitis     | 8 × 6              |
| 9       | 60  | F   | Radiotherapy| Spinal osteosynthesis | 26 wk Metastasis of kidney cancer | L1–L3             | 18 × 6             |
| 10      | 76  | M   | Radiotherapy| Spinal osteosynthesis | No Sacral chordoma| I4–S1             | N/A                |
| 11      | 77  | M   | Radiotherapy| Spinal osteosynthesis | 18 wk Sacral chordoma| T12–L5             | 15 × 3             |
| 12      | 72  | F   | Obesity, diabetes | Spinal osteosynthesis | 4 wk Material infection and postoperative dehiscence | Between L2 and S1 | 20 × 8             |
| 13      | 64  | F   | Obesity     | Spinal osteosynthesis | 5 wk Material infection and postoperative dehiscence | Sacrum             |                  |
| 14      | 67  | F   | No          | No             | No Malignant tumor excision with iliac crest resection Neuroendocrine tumor excision Merkel | T10–T12            | 10 × 8             |
| 15      | 62  | M   | Obesity, diabetes, chronic renal insufficiency | No | No Chronic fistula on infected material | T12–L5             | 15 × 3             |
| 16      | 55  | M   | Radiotherapy, diabetes | Spinal osteosynthesis | No Chronic fistula on infected material | Sacrum             | 15 × 6             |
| 17      | 64  | F   | No          | No             | No Exeresis        | L2–S1             | 12 × 7             |
| 18      | 46  | F   | No          | No             | No Squamous cell carcinoma | T12–L3            | 10 × 7             |
| 19      | 69  | F   | No          | No             | No Melanoma        | L5–S1             | 9 × 4              |
| 20      | 79  | F   | Radiotherapy| Spinal osteosynthesis | No Sacral chordoma | L5–S1             | 9 × 7              |
| 21      | 60  | F   | No          | No             | No Burns           | L2–L4             | 9 × 7              |
| 22      | 49  | F   | No          | No             | No Squamous cell carcinoma | L3–L4            | 19 × 7             |
| 23      | 52  | M   | No          | No             | No Basal cell carcinoma | L2–L3            | 8 × 5              |
| 24      | 60  | F   | No          | No             | No Melanoma        | L1–L2             | 3 × 3              |
| 25      | 51  | M   | No          | No             | No Melanoma        | L1–L2             | 6 × 4              |
| 26      | 78  | F   | Diabetes    | No             | No Spondylitis     | L3                | 8 × 6              |
| 27      | 46  | M   | No          | No             | No Dermatofibrosarcoma | L3–L4            | 14 × 6             |
| 28      | 45  | M   | Radiotherapy| Spinal osteosynthesis | 3 wk Sacral chordoma | L5–S1             | 12 × 6             |
| 29      | 80  | F   | Obese       | No             | No Basal cell carcinoma | L1–L2            | 11 × 5             |
| 30      | 89  | M   | Hypertension| No             | No Basal cell carcinoma | T10–T12           | 26 × 8             |

F, female; M, male.
2 months, so we decided to cover the exposed osteosynthesis material by a flap. A left LAP was harvested with a 14-cm × 5-cm skin paddle and a 90 degrees arc of rotation. Bacteriological samples were taken intraoperatively from both osteosynthesis material and soft tissues. The postoperative course was without complication, with a 6-week antibiotic coverage corresponding initially to broad-spectrum antibiotics and then adapted to samples over time. Eighteen months after surgery, there was no evidence of chronic infection of the osteosynthesis material.

Case No. 2 (Number 11 in Table 1) (Fig. 2)

A 77-year-old patient was treated for a lumbosacral chordoma by the neurosurgery team. The need for adjuvant radiotherapy, combined with the patient continuing to smoke, led to exposure of the osteosynthesis material. Two attempts at direct closure by the neurosurgery team and a prolonged period of NPWT over 4 months were all unsuccessful.

Thus, we used a LAP with a skin paddle of 16 cm × 7 cm, harvested on the right side, and which was turned with an arc of rotation of 100 degrees. The procedure was accompanied by antibiotic therapy for 6 weeks, again initially broad spectrum and then adapted to intraoperative sampling.

The postoperative period was marked by distal venous congestion and epidermolysis covering a 2-cm area without coverage failure. At 8 weeks, healing was complete. Due to chronic spinal pain, the patient still struggled to walk, but no longer required nursing care. Nine months postoperatively, there was no evidence of chronic infection of the osteosynthesis material, and tissue coverage was stable (Figs. 3–4).

RESULTS

From November 2012 to March 2019, we performed 32 LAPs on 31 patients. There were 17 men and 14 women with a mean age of 60.7 years (35–77). Loss of substance had various etiologies, including postoperative neurosurgical complications (n = 13), oncodermatologic resections (n = 15), deep burns (n = 2), and ballistic trauma (n = 1) (Fig. 5).

Twenty-nine defects were covered by a single LAP. One further patient required 2 LAPs, and yet another by a LAP combined with 2 S-GAPs. Defects averaged 11.3 cm (range 3–24) × 5.9 cm (range 3–10) and the LAP skin paddle averaged 14.3 cm long (range 8–26) × 6.5 cm wide (range 5–10). The average arc of rotation for LAPs was 131.3 degrees (range 70–180 degrees). Table 2 reports all of these clinical data.

In 10 cases, NPWT had previously been used, implemented for an average duration of 7.1 weeks. In 9 cases of osteosynthesis, material was present during the coverage procedure. In terms of comorbidities, 25.8% of patients had a history of radiotherapy (8/31), 19.4% of patients had diabetes (6/31), 12.9% were morbidly obese (4/31), and 6.5% had chronic renal failure (2/31). At least 10 smoked daily, but some patients did not report their true smoking status.
Fig. 2. Examples of cases. A, Wound dehiscence following radiotherapy with exposure of material in a patient having been treated for lumbosacral chordoma. B, Acoustic Doppler identification of the chosen perforator followed by drawing of the skin paddle. C, Flap harvesting. D, Dissection and partial skeletonization of perforator vessels. E, Placement of the flap on the defect with tension-free stitches and a primary closure of the donor site. F, At 3 months, healing was complete.

Fig. 3. A, A 73-year-old patient having undergone osteosynthesis surgery for vertebral collapse presented with spondylodiscitis secondary to postsurgical wound dehiscence. B, Acoustic Doppler detection of chosen lumbar perforating arteries was performed. Debridement of the septic zone followed, collecting bacteriological samples. C, Flap rotation of approximately 100 degrees. D, Placement of flap and suture without tension on drainage. The donor site was primarily closed. E, Results at 6 months showing definitive healing.
Some skin congestion at the flap site was noted; however, in 4 cases (12.9% of our series), no further coverage procedure was required. In 3 cases, this complication consisted of distal epidermolysis not exceeding 1.5–2 cm, and in 1 case, necrosis of 8 cm. All cases of distal skin necrosis were left as secondary healing with favorable outcome. No coverage failure was reported at an average follow-up of 9.7 months, nor were there any complications at the donor site, in all cases primarily closed.

DISCUSSION

Lumbar defects can be reconstructed in different ways, but few reliable local or locoregional coverage solutions exist in this anatomical area. Before the advent of perforator flaps, there was frequently no cover solution to offer to these patients.

V–Y advancement flaps, or other skin-pediced flaps can be proposed, but the range of their advancement is quite limited, especially in a cicatricial or postradiation context. Yoshino et al.14 reported the advantage of skin-pediced flaps compared to island flaps in terms of tension reduction, but Milton preferred the reliability of islands flaps.15 Indeed, the outcome of random fascio-cutaneous advancement flaps or rotation flaps is often very uncertain in patients with comorbidities or a history of radiotherapy.

The latissimus dorsi flap in its proximal pedicle version does not allow coverage of low lumbar locations, unless pedicle lengthening is performed by vascular bypass with saphenous vein graft interposition, as proposed by Duroure et al. Otherwise, it is then necessary to harvest this flap with its less reliable accessory pedicles and with increased risk of necrosis. Finally, the superior gluteal flap, which may be of interest for the loss of very low or lateral substance, is often of little use in medial lumbar reconstructions.

Thanks to a large transverse laxity of the donor site, the propeller version of LAP makes it possible to cover large loss of substance, regardless of the axis with a large degree of freedom. To date, LAPs have already been studied scientifically and theoretically in various cases of body reconstruction and especially as free flaps in breast reconstruction. Lumbar perforator pedicles are anatomically constant, and their preferential statistical localizations have already been studied. Boucher and Mojallal describe the cluster of the 4 lumbar perforators as a rectangle with a median limit at 4.5 cm from the median line, a lateral edge at 10 cm from the latter, an upper and lower limit located, respectively, 10 and 3 cm from the superior posterior iliac spine. The cluster of the fourth lumbar perforator is 6 cm from the median line, with a lateral edge 10 cm from the latter, an upper and lower limit, respectively, of 8 and 3 cm from the superior posterior iliac spine. In a radio-anatomical study of 10 cadaver hemithoraces and lumbar regions, Aho et al. measured the average location of the lumbar perforating arteries from the coccyx: 7.62 cm and from the median line: 5.14 cm.

If each of the 4 lumbar perforating pedicles can be used to harvest a LAP, it is obvious that the fourth pair (L4) is surgically the most interesting. Indeed, the L4 pedicle has the largest caliber. Kiil et al dissected 28 lumbar regions, finding an average diameter of 4 mm for the L4 pedicle (artery and veins) compared, respectively, to 2, 3.5 and 3.5 for L1, L2, and L3. Moreover, these authors also found that the L4 perforator pedicle most often had a septocutaneous path, facilitating dissection: 54%, in compared to 30%, 42%, and 38% for L1, L2, and L3. Average diameter of the lumbar perforating arteries was 0.8, 1.4, 1.7, and 1.8 mm for L1, L2, L3, and L4, respectively. The authors also estimated that L4 had the longest pedicle (measured between the vertebral body and the point of perforation of the thoracolumbar fascia) at an average of 106 mm, compared 98, 68, and 78 mm for L1, L2, and L3. Finally, the study showed that L4 (as well as L1) was significantly more arborized than L2 and L3.
The reliability of LAPs in covering lumbosacral defects has already been demonstrated in the literature in small series.\(^{17,20}\) Mathur et al in 2016 also reported a series of 102 perforator-plus flaps (with cutaneous bridge preservation) based on lumbar or gluteal perforators for lumbo-sacral substance loss and found only 3% of partial flap necrosis, with a mean follow-up of 1.5 years.\(^{19}\) In Mathur et al’s series, preservation of the cutaneous bridge at the flap base does not make it possible to rotate the flap more than 90 degrees and can create distortion during cutaneous suture.

In our experience, certain points are critical to achieve coverage goals and complication rate. Pedicle dissection must of course be carefully performed, and skeletonization must be adapted to each case to ensure rotation without tension on the perforators. The best approach, therefore, is to harvest the flap requiring the least rotation angle to limit twisting the perforator and the risking venous congestion. However, to be primarily closed, the donor site often requires a minimum angle of 90 degrees with loss of substance. Closure should be performed with loose stitches, to prevent postoperative congestive edema adding greater more volume to the flap. If this is not sufficient, removing a few sutures/stitches is always possible immediately postoperatively or within 6–12 hours following surgery, allowing the venous congestive phase to pass.\(^{24}\) We recommend placing drainage systems both at the donor site and under the flap. Repeated cleaning of this system also helps reduce the risk of infection.

As a general rule, it is common practice during coverage of bone exposure to remove, or at least change, any exposed osteosynthesis material to limit septic problems. In spinal injuries, where removing such material is often very difficult, if not impossible, we have chosen the coverage option, leaving the osteosynthesis material in place. It should be noted that, unlike the osteosynthesis material of long bones (upper and lower limbs), spinal, the coverage by means of a flap, makes it possible to more easily control chronic exposure, even after acute infection. Indeed, in our series, after a period of NPWT, it was never necessary to remove osteosynthesis material, and to date, at a mean follow-up of 8.14 months for this series of patients with hardware in place, no cases presenting infected material had septic recurrence, fistula, or new exposure of the material.

Ultimately, our series of 32 propeller LAPs, carried out in the Toulouse and Strasbourg University hospitals by surgeons skilled in using perforator flaps, highlighted the reliability of these flaps that can be widely proposed to patients in pertinent clinical contexts. Despite the variety of etiologies encountered, and the frequent comorbidities of these patients, LAPs are a solution of choice, with low donor site morbidity. Consequently, we believe that this procedure should be taught to all reconstructive surgeons.

### Table 2. Clinical Data

| Patient | Defect (cm) | Lap Size (cm) | No. Flap | Rotation (Degree) | Follow-up (mo) | Flap Complications | Donor Site Complication | Primarily Closed | Donor Site |
|---------|-------------|---------------|----------|------------------|--------------|--------------------|------------------------|-------------------|------------|
| 1       | 5 × 5       | 8 × 6         | 1        | 180              | 12           | No                 | No                     | Yes               |            |
| 2       | 7 × 4       | 8 × 5         | 1        | 180              | 12           | No                 | No                     | Yes               |            |
| 3       | 10 × 7      | 11 × 7        | 1        | 150              | 12           | No                 | No                     | Yes               |            |
| 4       | 24 × 7      | 24 × 7        | 1        | 120              | 18           | One-third distal necrosis | No                     | Yes               |            |
| 5       | 8 × 5       | 13 × 7        | 1        | 150              | 9            | No                 | No                     | Yes               |            |
| 6       | 3 × 3       | 12 × 5        | 1        | 150              | 12           | No                 | No                     | Yes               |            |
| 7       | 6 × 4       | 12 × 6        | 1        | 150              | 3            | No                 | No                     | Yes               |            |
| 8       | 8 × 6       | 13 × 5        | 1        | 100              | 18           | Delayed healing     | No                     | Yes               |            |
| 9       | 18 × 6      | 13 × 6 and 13 × 6 | 2   | 90               | 6            | No                 | No                     | Yes               |            |
| 10      | N/A         | 14 × 6        | 1 LAP + 2 S-GAP | 150  | 12           | No                 | No                     | Yes               |            |
| 11      | 15 × 5      | 16 × 7        | 1        | 100              | 12           | Superficial necrosis on 2 cm (distal) | No                     | Yes               |            |
| 12      | 15 × 8      | 20 × 8        | 1        | 110              | 6            | No                 | No                     | Yes               |            |
| 13      | 20 × 8      | 25 × 10       | 1        | 80               | 4            | No                 | No                     | Yes               |            |
| 14      | 8 × 8       | 15 × 6        | 1        | 180              | 1            | No                 | No                     | Yes               |            |
| 15      | 10 × 10     | 26 × 9        | 1        | 90               | 4            | No                 | No                     | Yes               |            |
| 16      | 15 × 3      | 20 × 6        | 1        | 70               | 8            | No                 | No                     | Yes               |            |
| 17      | 15 × 6      | 23 × 8        | 1        | 90               | 7            | No                 | No                     | Yes               |            |
| 18      | 12 × 7      | 13 × 7        | 1        | 180              | 4            | No                 | No                     | Yes               |            |
| 19      | 10 × 7      | 11 × 7        | 1        | 180              | 9            | No                 | No                     | Yes               |            |
| 20      | 5 × 6       | 8 × 6         | 1        | 180              | 12           | No                 | No                     | Yes               |            |
| 21      | 9 × 4       | 9 × 5         | 1        | 180              | 12           | No                 | No                     | Yes               |            |
| 22      | 9 × 7       | 10 × 6        | 1        | 130              | 12           | No                 | No                     | Yes               |            |
| 23      | 19 × 7      | 19 × 7        | 1        | 120              | 18           | No                 | No                     | Yes               |            |
| 24      | 8 × 5       | 10 × 7        | 1        | 150              | 9            | No                 | No                     | Yes               |            |
| 25      | 3 × 3       | 10 × 6        | 1        | 150              | 12           | No                 | No                     | Yes               |            |
| 26      | 6 × 4       | 11 × 6        | 1        | 120              | 3            | No                 | No                     | Yes               |            |
| 27      | 8 × 6       | 13 × 5        | 1        | 90               | 18           | No                 | No                     | Yes               |            |
| 28      | 14 × 6      | 13 × 6        | 1        | 90               | 6            | No                 | No                     | Yes               |            |
| 29      | 12 × 6      | 14 × 6        | 1        | 150              | 12           | No                 | No                     | Yes               |            |
| 30      | 11 × 5      | 11 × 5        | 1        | 100              | 12           | No                 | No                     | Yes               |            |
| 31      | 26 × 8      | 20 × 8        | 1        | 110              | 6            | Distal congestion | No                     | Yes               |            |

For patient 31: Distal congestion (1 cm of necrosis)
CONCLUSIONS

LAPs can be used for lumbosacral defects with a wide variety of etiologies. The propeller LAP is a reliable and efficient surgical procedure making it possible to harvest a large skin paddle with low donor site morbidity. This series of 31 patients confirms the data found in the literature, with no reports of any failure of coverage, even in patients with significant comorbidities. The reconstructive surgeon should propose it to patients as a first-line option where surgery is indicated.

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