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Reconstruction of Spinal Soft Tissue Defects With Perforator Flaps From the Paraspinal Region

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Abstract. *Background/Aim: Reconstruction of spinal soft tissue defects is challenging, especially when neural structures or prosthetic material are exposed. They should be covered with well-vascularized tissue such as paraspinal perforator flaps. Materials and Methods: This is a retrospective study of soft tissue reconstructions with paraspinal perforator flaps from 2011 to 2018. The technique is described and risk factors for poor wound healing were assessed. Postoperative complications are reported. Results: Twenty patients with a mean age of 63.65 years were included. Defects had an average size of 47 cm^2 and were mainly located in the lumbosacral region (9 patients). Twelve patients suffered from infection following spinal stabilization, seven of whom were diagnosed with osteomyelitis, two patients presented with pressure sore and one patient experienced wound dehiscence. One partial flap necrosis with a lumbar defect occurred, which required revision surgery. No total flap loss occurred. Stable, closed wounds were achieved at their final follow-up. Conclusion: Perforator paraspinal flaps are suitable for immediate reconstruction of spinal defects.*

Posterior trunk soft tissue defects represent a reconstructive challenge, especially in the case of exposed vertebral hardware, spinal cord and cerebrospinal fluid leakage. Defects can derive from trauma, tumor resection or debridement following postoperative infections. Indeed, wound dehiscence following spinal surgery, which particularly strikes on polymorbid or cachectic patients, may finally lead to deep infections with the frightening risk of osteomyelitis.

The ideal treatment includes effective debridement and defect coverage with well-vascularized tissue that obliterates dead space. Conventional treatment options have mainly focused on muscle or myocutaneous flaps, such as *trapezius* or *latissimus dorsi* muscle flaps, although their significant donor site morbidity represents a well-known disadvantage (1). In the era of perforator flaps, surgeons have largely searched for evidence regarding whether muscle or myocutaneous flaps should be preferred to fasciocutaneous flaps to prevent infections (2). On the other hand, a clear advantage of perforator flaps is the reduced donor site morbidity (3). The present study aimed to assess feasibility and reliability of perforator flaps from the paraspinal region for coverage of complex spinal defects, and their long-term outcomes.

Materials and Methods

Twenty consecutive patients suffering from spinal soft tissue defects underwent soft tissue reconstruction with perforator flaps from the paraspinal region between 2011 and 2018 (Table I). A retrospective analysis was performed on a prospectively maintained database. Spinal soft tissue defects were present in the cervical, thoracic, lumbar and sacral regions due to vertebral stabilization, tumor resection or debridement following postoperative infections (wound dehiscence, infection and secondary osteomyelitis). Risk factors such as smoking, obesity, steroids, hypertension, collagen-vascular diseases, paralysis, and malnutrition were, together with defect characteristics (size, localization) and duration of surgery are shown in Table II.

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Table I. *Patients characteristics and demographics.*

Patients (n)	20 (11 male, 9 female)
Age (y)	63.65 (26-86)
Etiology of defect (n, %)	Complication after spinal stabilization (n=15, 75%)
	- 12 infection (7 including osteomyelitis)
	- 2 pressure sore
	- 1 wound dehiscence
	Other (n=5, 25%)
	- 3 tumor resections (melanoma, sarcoma)
	- 2 internal iliac artery compromise
Hardware exposure (n, %)	5, 25%
Dural exposure (n, %)	3, 15%
CSF leak (n %)	1, 5%

Postoperative outcomes were assessed for, minor and major complications, the need for hardware removal, duration of antibiotic treatment, total length of hospitalization, length of hospital stay after flap reconstruction and length of follow-up (Table III). Postoperative flap-related complications such as haematoma, infection, seroma, wound dehiscence and partial flap necrosis were assessed and classified as minor or major complications, depending on whether a reoperation was necessary or not (Table II).

The investigation was approved by the local ethical committee and was conducted in accordance with the principles of Declaration of Helsinki.

Surgical technique. All reconstructions were secondary, with Vacuum dressing used as a bridging procedure for the final reconstruction.

In case of spinal defect with prosthetic material, decision was made if vertebral instrumentation was retained or exchanged in an interdisciplinary meeting (Departments of Infectious Diseases, Spinal Surgery and Plastic Surgery). In cases where previous surgeries may have jeopardized vascularization, angiographic CT or MRI was performed to map perforators in the paraspinal region adjacent to the defect.

After extensive debridement, vertebral bone biopsies (histology and microbiology) were taken and patients received wide spectrum IV antibiotics, while waiting for a definitive antibiogram. Following debridement, perforator location was verified with hand-held Doppler. Flap design was defined according to the paraspinal perforator position and the need for dead space obliteration.

Flaps were raised at the subfascial level (*e.g.* cervical, thoracal, lumbar or sacral fascia) (Figure 1). If the required flap rotation was less than 90˚, dissection at the perforator level was performed to a minimum, leaving as much subcutaneous tissue and skin as possible intact to maximize venous and lymphatic drainage. If perforator flap rotation of more than 90˚ was planned, dissection of the vascular pedicel was performed as far down to the source vessel as necessary to facilitate rotation (Figure 2). The elevated flap was then transposed or rotated into the defect and partially de-epithelialized if large dead space had to be filled. The wounds were closed over a suction drain. Postoperative care included immediate mobilization whenever possible.

Table II. *Risk factors for wound complication. Risk factors for wound complications (major and minor) together with wound characteristics (localization and size). Duration of the surgery for reconstruction.*

Risk factor	Patients
Smoking (n, %)	6, 30%
Obesity (n, %)	5, 25%
Steroids (n, %)	3, 15%
Hypertension (n, %)	7, 35%
Collagen - vascular disease (n, %)	1, 5%
Palsy (n, %)	3, 15%
Malnutrition (n, %)	8, 35%
Diabetes (n, %)	6, 30%
Defect location (n, %)	3, 15% cervical
	8, 40% thoracal
	9, 45% lumbosacral
Defect size (cm^2)	47 (9-150)
Duration of surgery (min)	153 (45-367)

CSF: Cerebrospinal fluid.

Results

Twenty consecutive patients (11 male, 9 female) with a mean age of 63.65 years (range=26-86 years) with spinal soft tissue defects treated with perforator flaps from the paraspinal region between 2011 and 2018 were included into the study (Table I). Defects averaged 47 cm^2 (range=9-150 cm^2) in size and were mainly located in the lumbosacral region (9 patients, 45%) followed by the thoracic region (8 patients, 40%) and the cervical region (3 patients, 15%). Hardware was exposed in five patients. Three patients suffered from exposed dura and one patient from CSF leakage. Etiology of the spinal soft tissue defects was mainly postoperative early infection following spinal stabilization (12 patients, 60%). Among the eleven patients that developed infection, seven patients had osteomyelitis (Table I).

Table III. *Surgical outcome and complications*.

Minor complications (n) (hematoma, seroma, infection, skin slough, partial flap necrosis and wound dehiscence)	5, 25%
Major complications (n) (total flap loss, need for reoperation)	1, 5%
Hardware removal (n)	0
Antibiotic treatment (weeks)	7.8 (1-15)
Hospitalization time after flap reconstruction (days)	20.05 (3-36)
Hospitalization time (days)	28.75 (6-68)
Length of follow-up (months)	13.4 (2-20)

Malnutrition (8 patients, 40%), hypertension (7 patients, 35%) and smoking (6 patients, 30%) were the most common risk factors among the study population (Table II). Analysis revealed 16 out of 20 patients (80%) with 2 or more risk factors for poor wound healing (Figure 3).

Average duration of surgery (reconstruction) was 153 min (45-367 minutes). Mean follow-up was 13.4 months (range=4-20 months). Minor complications occurred in five patients (25%, Table III). Only one wound dehiscence was observed. A partial distal flap loss (major complication) was observed in one patient requiring revision surgery with debridement and further advancement of the perforator flap. No total flap loss occurred. No hardware removal or change was necessary. Mean antibiotic treatment was 7.8 weeks (range=0-15 weeks) after defect closure. Duration of the total hospital stay averaged 28.75 days (range=6-68 days), whereas the average hospital stay after reconstruction was 20.05 days (range=3-36 days) (Table III).

Discussion

Complex midline back soft tissue defects are traditionally treated with muscle or myocutaneous flaps, due to earlier experimental studies suggesting the superiority of muscle flaps compared to random pattern fasciocutaneous flaps in treating infected wounds (4, 5). Furthermore, muscle flaps may guarantee pliability and the advantage to better fill the dead space. However, muscle flaps can frequently lead to significant donor site morbidity, which often requires complementary skin graft (6).

Perforator flaps extend the reconstructive armamentarium while preserving muscle function and subsequently minimize donor site morbidity (7-9). Perforator flaps rely on a vascular pedicle that leads to the overlying fascia or skin only. Each perforator has its own and reliable arterial vascular territory "perforasome" which are linked with adjacent perforasomes by "linking vessels" (10). The flap design, therefore, depends on the size of the perforasome of the perforator. Experimental work in a rabbit model showed no statistical difference in wound healing in superficial and deep infections between latissimus dorsi musculocutaneous flaps and thoracodorsal artery perforator based fasciocutaneous flaps. Various clinical studies using perforator flaps challenged the notion that infected wounds or osteomyelitis should be covered with muscle tissue (11, 12). These studies concluded that the type of flap used for reconstruction, is less critical for the final outcome if basic concepts of radical debridement of necrotic and infected tissue and the need for dead space obliteration were respected.

Perforator flaps from the paraspinal cervico-thoraco-lumbar region for spinal defect coverage ideally follow the "like with like" tissue replacement principle of plastic surgery. These flaps are nourished by medial and lateral dorsal cutaneous branches of the intercostal artery, that supply the spinalis and longissimus muscle before reaching the skin, just lateral to the spinous processes. Minabe *et al*. found nine pairs of dorsal intercostal artery perforators (DICAPs) measuring 0.5 to 1 mm in diameter within 5 cm of the spinous processes (8). Perforator flaps from the paraspinal region in the upper thoracic area can be extended up to the anterior border of the latissimus dorsi muscle, due to choke anastomoses with the scapular circumflex artery and cutaneous branches of the thoracodorsal artery. Similarly, in the lower thoracolumbar part, perforator flaps can be harvested to the iliac crest due to choke anastomoses with lumbar arteries and/or the thoracodorsal artery. In between the seventh and ninth vertebral body, musculocutaneous perforators from the paraspinous muscle are more dominant than the DICAP of the same level supplying the middle back skin. The length of the perforator was 1-3 cm subfascially for upper DICAP and 4-10 cm of length for the lower DICAP, respectively. Furthermore, De Weerd *et al*. introduced the sensate DICAP flap for closure of cervicothoracic midline defects after spinal surgery, which was raised longitudinally from lateral to medial (13). In a cadaveric study, the authors found a reliable course of the medial DICAP and all of the medial and lateral DICAPs were accompanied by a cutaneous nerve, providing protective sensibility to the reconstructed area. This would serve as an advantage of the perforator flap compared to muscle flap options.

In our hands, soft tissue defects of the posterior trunk or spinal area can be successfully treated using paraspinal

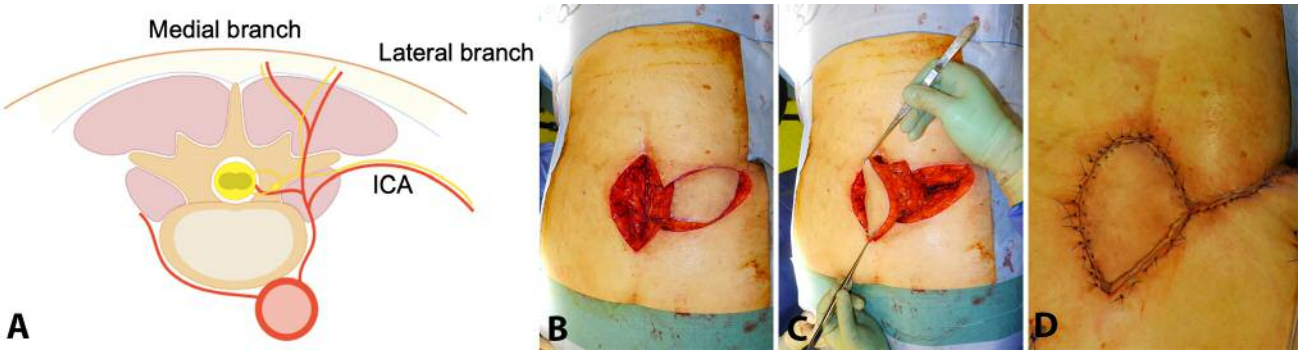

Figure 1. *Paraspinal perforators vascularization. (A) Scheme of the paraspinal perforators originating from the dorsal intercostal artery (DICA) and splitting in a medial and lateral branch. (B) Intraoperative images of a lumbal spinal defect with a paraspinal perforator flap dissected and rotated 90˚ for defect closure.*

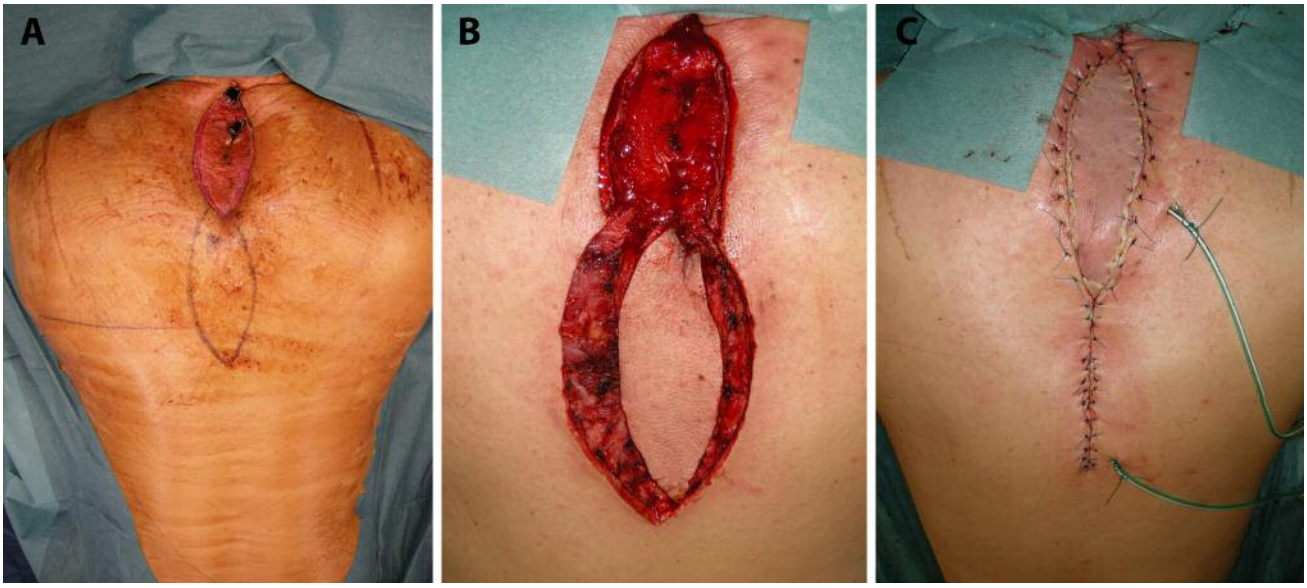

Figure 2. *Operative pictures. Intraoperative pictures from male patient with a cervical spine defect after fusion. (A) Paraspinal perforator flap is designed and (B) harvested and rotated 180˚ for defect closures (C).*

perforator flaps with low donor site morbidity. In our retrospective study including 20 patients, we observed a similar complication rate in paraspinal perforator flaps compared to muscle flap coverage (14). From our experience, complete dissection of perforators should be minimized in flap rotation is less than 90˚. A skin bridge of the flap should be preserved whenever possible to increase lymphatic and venous drainage. If a flap rotation of more than 90˚ is needed, the vascular pedicel should be dissected as far down to the source vessel as necessary, to allow the torsion of the pedicle to be distributed over a longer distance. Soft tissue defects of the present study had an average size of 47 cm^2 with a range from 9 to 150 cm^2. According to Prasad *et al.*, maximum flap dimension of perforator flaps from the paraspinal (DICAP) region might be up to 40 × 15 cm (15). Similar studies, even if based on smaller series, report the use of paraspinal flaps to cover posterior trunk defects (16, 17). Their overall flap complication rate ranged between 0% and 42.8%, including all types of complications (major and minor together). In the present study, we report an overall complication rate of 30% (including both minor and minor complications), with only 5% of patients requiring further surgery (Table III).

These previous studies evaluated the feasibility of perforator-based flaps mostly in defects occurring after tumor resection. Our study population consisted mostly of spinal surgery wounds with implanted hardware.

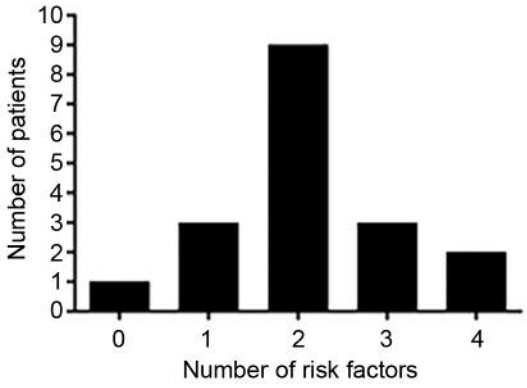

Figure 3. *Distribution of risk factors. Most patients had at least 2 risk factors (smoking, obesity, steroids, hypertension, collagen – vascular disease, palsy, malnutrition, diabetes).*

Spinal surgery often involves implantation of foreign material. In contrast to extremity reconstruction, perseveration of the hardware is often inevitable, due to lack of therapeutic alternatives, which would ensure stability of the spine (18). This makes subsequent treatment of infections particularly challenging (19).

Indeed, hardware removal in case of deep wound infection remains controversial. Studies have shown that early onset exposed hardware (within one month after initial spinal surgery) with deep infections can be retained, whereas in late onset (>1 month) deep infections, complete hardware removal seems to have a superior outcome (20-22). Duration of infection and hardware exposure are relevant prognostic factors for the salvage of exposed hardware covered with soft tissue (23). In this sense, debridement of the infected wound should be fulfilled within 2 weeks after signs of infection (24), and coverage of a wound with exposed hardware should occur within 3 weeks (25).

In our series, only early infections were present. Debridement and reconstruction of the defect occurred within a maximum of 10 days. No hardware removal was performed. Our study supports the use of perforator flaps applied to spinal defects as a treatment option even in case of early-stage hardware exposure (<1 month).

In our series, we exclusively performed delayed defect restoration. Most recent articles propose prophylactic (immediate) wound coverage with well-vascularized tissue in high-risk patients, to decrease the incidence of postoperative wound healing complications after spinal surgery (4, 14). In published studies regarding benefits of immediate reconstruction, mostly muscle flaps were used for defect closure (4, 18, 26). We feel that further studies about the feasibility of immediate reconstruction with perforator flaps should be conducted.

The main drawback for the present study is the relatively small number of patients and its retrospective design. A disadvantage of perforator flaps from the paraspinal region is their limited value in filling dead space, especially in the cervicothoracic region. Partial de-epithelialization of the flap may provide additional volume to fill a cavitary lesion and in part overcome this limitation. In case of perforator flap failure or soft tissue defect recurrence, perforator flaps from the contralateral paraspinal region or underlying paraspinal muscle flaps could be harvested as a secondary reconstructive option. Moreover, such flaps do not exclude the possibility of harvesting axial myocutaneous flaps (*e.g.* trapeze), increasing in this way the armamentarium of the reconstructive surgeon is such complex clinical scenarios.

Conclusion

Perforator flaps from the paraspinal region can provide a valid alternative for patients with comorbidities, even in case of hardware exposure. We recommend the preoperative assessment of perforator position and size by Doppler probe or angiographic CT scan/MRI in complex situations for optimal flap design planning. The perforator flaps from the paraspinal region are dissected fast, rely on constant perforators and have minor donor site morbidity.

Conflicts of Interest

The Authors declare that they have no conflicts of interest regarding this study.

Authors' Contributions

Pietre G. di Summa (PGDS), René D. Largo (RDL), Tarek Ismail (TI) and Swenn Maxence Krähenbühl (SMK) were responsible for drafting the manuscript. PGDS, RDL, Stefan Schaeren (SS) and Daniel F. Kalbermatten (DFK) were responsible for the surgical intervention provided to the patients. PGDS, RDL, TI, Mathias Tremp (MT), Alexander Lunger (AL), Reto Wettstein (RW), SMK, Salvatore Giordano (SD), Dirk J. Schaefer (DJS), SS and DFK were responsible for the critical review and correction of the manuscript.

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