In today’s military operations in the territory of Ukraine, a particularly acute and urgent issue is treating victims of military trauma. One component of a plastic surgeon’s work is to restore extensive and deep wound defects in a short period of time and provide a high degree of functional recovery to the damaged area. Because many injuries caused by military operations cannot be closed using a primary suture, the specialist has to select another surgical approach to close the wound defect. Surgeons must select methods that not only cover the extensive wound defect in 1 step but also allow skin coverage that is anatomically, functionally, and visually similar to the surrounding tissues to reduce the length of the hospital stay and ensure optimal functional recovery of the damaged organ.

Methods: From 2014 to 2015, 25 patients underwent 36 reconstructions at our center after receiving mine-shrapnel and gunshot wounds. All reconstructions occurred during the acute period and used keystone island perforator flaps. The authors’ wound management technique was characterized by an aggressive surgical and antibiotic therapy protocol.

Results: In all cases, after surgical debridement, the mine-shrapnel and gunshot wound defects were completely closed in 1 stage during the acute period. The working time in the operating room to perform the transposition of the flap ranged from 45 to 90 minutes, with an average of 68 minutes. All displaced flaps were similar in structure and color to the surrounding tissues and did not change the contours of the body. The adequate restoration of skin allowed patients to begin early recovery of functional activity.

Conclusions: Local keystone island perforator flaps can be considered one of the primary methods of plastic closure of extensive defects caused by mine-shrapnel and gunshot wounds at different anatomical locations, providing that the tissue surrounding the defect is intact and usable as a donor resource. (Plast Reconstr Surg Glob Open 2016;4:e723; doi: 10.1097/GOX.0000000000000736; Published online 26 May 2016.)

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active zones and support surfaces, and the inability to use skin grafting in cases in which deep anatomical structures remain open until granulation tissue forms. In the acute period, the combination of these factors makes repairing such defects using local flaps, including the perforator artery, a priority, and this is reflected in the trends of modern reconstructive surgery. This type of surgery allows us to not only cover extensive wound defects in 1 step but also provide skin coverage that is largely anatomically, functionally, and visually similar to the surrounding tissues, which reduces the length of hospital stay and ensures optimal functional recovery of the damaged organ.3–7

The aims of this study were to improve the efficiency of plastic reconstructions using keystone island perforator flaps in patients with military trauma and to report and analyze the results of reconstruction for extensive gunshot and mine wounds during the acute period.

### PATIENTS AND METHODS

#### Case Study

During the period of hostilities in Ukraine from 2014 to 2015 (Anti-Terrorist Operation), 25 patients experiencing mine-shrapnel and gunshot wounds underwent 36 reconstructions in the Burn and Plastic Surgery Centre in the acute period using keystone island perforator flaps.8 All patients were male and were between the ages of 21 and 53 years. Flap preplanning was carried out using audio Doppler (8 MHz) to determine the location of the perforator vessels. The authors’ wound management technique is characterized by an aggressive surgical and antibiotic therapy protocol. Patients received vacuum-assisted closure therapy for 2 to 3 days, followed by radical surgery using the keystone island perforator flap technique. The patient characteristics and flap parameters are shown in Table 1.

#### Table 1. Patient Characteristics and Flap Parameters

| Case No. | Age  | Sex | Etiology of Damage | Flap No. | Wound Defect Location | Flap Size (cm) | Complications |
|----------|------|-----|--------------------|----------|-----------------------|----------------|---------------|
| 1        | 24   | M   | Gunshot wound      | 1        | Right thigh, anterior surface | 5 × 14 | No |
| 2        | 53   | M   | Mine blast wound   | 2        | Left thigh, medial surface   | 10 × 22 | No |
| 3        | 36   | M   | Mine blast wound   | 3        | Right shin, anterior surface | 6 × 16 | Partial flap necrosis |
| 4        | 26   | M   | Gunshot wound      | 4        | Left shin, lateral surface   | 4.5 × 11 | No |
| 5        | 30   | M   | Mine blast wound   | 5        | Left shoulder, lateral surface | 9 × 12 | No |
| 6        | 38   | M   | Mine blast wound   | 6        | Left shoulder, medial surface | 6 × 12 | No |
| 7        | 23   | M   | Mine blast wound   | 7        | Right thigh, lateral surface  | 7 × 16 | No |
| 8        | 38   | M   | Mine blast wound   | 8        | Right shoulder, anterior surface | 6 × 15 | No |
| 9        | 39   | M   | Burns              | 9        | Right buttock, back and lateral surfaces | 12 × 22 | No |
| 10       | 28   | M   | Mine blast wound   | 11       | Left shin, lateral surface   | 6 × 31 | No |
| 11       | 21   | M   | Mine blast wound   | 12       | Left thigh, anteromedial surface | 7 × 23 | No |
| 12       | 43   | M   | Gunshot wound      | 13       | Right shin, lateral surface   | 4 × 16 | No |
| 13       | 33   | M   | Mine blast wound   | 14       | Right thigh, lateral surface  | 5 × 13 | No |
| 14       | 45   | M   | Mine blast wound   | 15       | Left thigh, medial surface    | 6 × 16 | No |
| 15       | 27   | M   | Gunshot wound      | 16       | Left thigh, lateral surface   | 7 × 18 | No |
| 16       | 25   | M   | Mine blast wound   | 17       | Right shin, medial surface    | 7 × 17 | No |
| 17       | 25   | M   | Mine blast wound   | 18       | Left shin, lateral surface    | 3.5 × 9 | No |
| 18       | 35   | M   | Mine blast wound   | 19       | Right shin, back surface      | 4 × 13 | No |
| 19       | 40   | M   | Gunshot wound      | 20       | Left shin, medial surface     | 8 × 18 | No |
| 20       | 25   | M   | Mine blast wound   | 21       | Right shin, medial surface    | 5 × 12 | No |
| 21       | 22   | M   | Mine blast wound   | 22       | Right shin, lateral surface   | 3 × 11 | No |
| 22       | 25   | M   | Mine blast wound   | 23       | Left shoulder, lateral surface | 5 × 14 | No |
| 23       | 23   | M   | Mine blast wound   | 24       | Right shin, lateral surface   | 8 × 4  | No |
| 24       | 47   | M   | Mine blast wound   | 25       | Right shin, anterior surface  | 5 × 14 | No |
| 25       | 29   | M   | Gunshot wound      | 26       | Left shin, medial surface     | 7 × 16 | No |
| 26       | 22   | M   | Mine blast wound   | 27       | Right shoulder and forearm, lateral surface | 3 × 8 | Suture diastasis of 2 cm |
| 27       | 25   | M   | Mine blast wound   | 28       | Right shin, anteromedial surface | 8 × 29 | No |
| 28       | 25   | M   | Mine blast wound   | 29       | Right shoulder, medial surface | 4 × 12 | No |
| 29       | 25   | M   | Mine blast wound   | 30       | Right shoulder, lateral surface | 8 × 16 | No |
| 30       | 25   | M   | Mine blast wound   | 31       | Right shin, anterior surface  | 8 × 4  | No |
| 31       | 25   | M   | Mine blast wound   | 32       | Left shin, anterior surface    | 5 × 14 | No |
| 32       | 25   | M   | Mine blast wound   | 33       | Left shin, medial surface     | 5 × 15 | No |
| 33       | 25   | M   | Mine blast wound   | 34       | Left shin, medial surface     | 6 × 16 | No |
| 34       | 25   | M   | Mine blast wound   | 35       | Left knee joint, medial surface | 6 × 18 | No |
RESULTS

In all cases, the mine-shrapnel and gunshot wound defects were closed completely after surgical debridement in 1 stage during the acute period. Patients were discharged to convalesce or were sent to a traumatological or neurosurgical department or a military hospital after complete healing of wounds from multiple injuries. All flaps survived without critical complications. In 1 case, partial necrosis of 1×3 cm was excised, and the wound was sutured. This patient had a history of trophic disorders of the lower extremities associated with continual vibration (vibration disease). In another case, there was a 2-cm wound dehiscence after removal of the sutures. The working time in the operating room for performing the transposition of the flap ranged from 45 to 90 minutes, with an average of 68 minutes. All displaced flaps were similar in structure and color to the surrounding tissues and did not change the contours of the body. In addition, a benefit of this method is that there was no donor site defect, which is common in most flap procedures. Adequately restored skin allows patients to begin recovering functional activity quickly.

The following clinical cases demonstrate the results of the keystone island perforator flap procedure in different locations.

Clinical Cases
Case 6 (Arm)

A 38-year-old man with gunshot wounds on the right shoulder, back and right hip was presented. On the lateral surface of the right shoulder, there was a deep 12×6 cm extensive wound defect (Fig. 1). A 7×16 cm keystone island perforator flap was used to cover the tissue defect (Fig. 2).

Fig. 1. The wound defect on the lateral surface of the right shoulder.

Fig. 2. The wound defect of the shoulder after surgical debride-ment and mapping the perforator keystone island flap. The green points indicate the perforating vessels, which will be stored during dissection, mobilization, and transposition of the flap.

After transposition, the flap was adapted to the edges of the wound and fixed with interrupted sutures without tension (Fig. 3). The space under the flap was drained with vacuum drainage for 3 days. The operation time was 50 minutes. The postoperative course was uneventful, the sutures were removed on the 14th day, and the patient was discharged from the hospital for recovery. A follow-up 22 days after surgery demonstrated adequate recovery without disruption in the contours of the upper limb or functional disorders (Fig. 4).

Case 10

A 28-year-old man with mine-shrapnel wounds to both lower extremities and the right hand
(polytrauma) was presented. On the right leg, there were 2 oval-shaped defects measuring 6 × 12 cm and 6 × 10 cm after debridement of the wounds (Fig. 5). The 2 defects were merged and closed using 1 flap. The perforator keystone flap 6 × 31 cm (Fig. 6) was moved to the defect to adapt to the edges of the wound without tension. The space under the flap was drained with vacuum drainage for 5 days (Fig. 7). The operation time was 95 minutes. A follow-up at 20 days after surgery showed adequate recovery without any apparent disruption of the contours of the leg or donor defect (Fig. 8).

This patient also had wounds on the left thigh. The size of 1 wound was 7 × 16 cm (Fig. 9). On the front of the thigh, a 7 × 23 cm perforator keystone island flap was formed laterally to the wound (Fig. 10). After mobilization, the flap was moved to the wound defect area and was fixed to the edges of the wound (Fig. 11). The operation time was 55 minutes. A follow-up 20 days postoperatively showed adequate recovery without disrupting the contours of the thigh or a secondary defect in the donor area (Fig. 12). The function of both lower limbs was restored.

**DISCUSSION**

Our plastic surgery method using displaced local perforator keystone island flaps demonstrated high efficiency in the operative closure of extensive mineshrapnel and gunshot wounds in the acute period for different locations.

The basic justifications for the widespread use of the described method are as follows: (1) the modern
study of the axillary blood supply of human cover tissues through the perforating arteries can be used effectively in clinical practice, with over 370 angiosomes available for any location; (2) the special design and preparation of the local perforator keystone island flap is limited and also raises the possibility of using this type of local flap due to the rapid recovery of tissue blood flow and the reduced risk of ischemic and venous congestion complications; and (3) this method has a relatively short operating time and eliminates the need to diagnose the presence and function of the main perforator vessel of the pedicle flap. Therefore, this method can be used on almost any part of the human body that requires a rapid and guaranteed closure of wound defects and is well suited to patients with extensive mine-shrapnel and gunshot wounds in the acute period.

One-stage reconstruction of extensive soft tissue defects, as opposed to multistage surgery, is recognized as a priority in plastic surgery. This type of reconstruction allows the fastest primary closure of soft tissue defects and improves the effectiveness of treatment in terms of both functional and aesthetic aspects. Perforator keystone island flaps can be an adequate alternative to skin grafting due to the quality of the tissues and an alternative to the 2-stage method of cross-plastic or free flap plastic surgery. This method significantly reduces rehabilitation time and material costs. In terms of the selected artery, the keystone flap method is much better than free flaps or perforator flaps in operation time. According to our data, the average time to complete this surgery is 68 minutes. The work of
Behan et al.\textsuperscript{8,13} and Khouri et al.\textsuperscript{7} fully confirm this finding, although the authors noted that the operating time may also depend on the size of the defect. Other perforator island flap methods take up to 120 minutes. In the case of a microsurgical anastomosis technique for the transplantation of free flaps, the operation time increases to between 2.5 and 8 hours even with 2 teams of surgeons.\textsuperscript{12} The relatively simple design of local perforator keystone island flaps and the elimination of the need for invasive x-ray diagnostics during flap preplanning allow us to recommend this technique for the adequate recovery of lost tissue with complete skin-fascial coverage, a minimum operational risk, and excellent functional and aesthetic results in patients with military injuries.\textsuperscript{2,5,7,13} Other advantages of this method include a more stable blood supply to the displaced tissues with rapid postoperative recovery of perfusion compared with other types of flap procedures; minimal damage to the donor area; acceptable functional and aesthetic results in the restored area; and a good “cost-effectiveness” parameter.\textsuperscript{5,7,11,14}

**CONCLUSIONS**

This method of transposing a keystone island perforator flap for the surgical closure of extensive mine-shrapnel and gunshot wounds in the acute period improves the efficiency of reconstructive surgery in patients with war injuries. Our results demonstrate the ease of flap preplanning and the simplicity and high reliability of the operation. In most cases, this method allows the closure of an extensive defect in 1 step without the need for intraoperative visualization and skel-etonization of perforating vessels in the flap pedicle. These benefits are reflected in the low rate of postoperative complications and in the absence of secondary donor defects that occur with other methods.

Local keystone island perforator flaps can be considered one of the primary methods of plastic closure of extensive defects caused by mine-shrapnel and gunshot wounds at different anatomical locations, providing that the tissue surrounding the defect is intact and usable as a donor resource.

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