Random Perforator Flap: Some Experiences with Keystone Flap

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Background: In reconstructing challenging defects, surgeons are considered fairly fortunate when they are able to obtain a similar donor tissue quality to that of the missing tissue; in regards to their color, texture, size, and the ease of donor transfer to the defect. Several methods may be used, which frequently include the free tissue transfers using microvascular anastomoses bearing their specific consequences. We report a select of challenging cases which were successfully reconstructed using the Keystone flaps and avoid microvascular anastomoses, where otherwise the free tissue transfers would be the typical option for closure in such defects.

Patient and Method: Nine cases of relatively large defect in various locations were reconstructed using the Keystone flaps supplied by either non-identified perforators or identified reliable perforators.

Result: Out of the 9 defects located on various region of the body (lumbar, thorax, dorsum of the foot, planter of the foot, posterior leg, sacrum, and cervicofacial) only the first 2 cases had identifiable perforators. All flaps survived completely without problem of vascularization.

Summary: The Keystone flap is a useful and reliable random perforator-based flap even when the perforator vessels are not identified.

Keywords: Keystone flap, small perforators, perforator flap

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not always provide the same tissue quality that compares to neighboring tissue. We present several cases of challenging defect reconstructions using the Keystone flap, where typically the free flaps would be the choice of reconstruction, evading the need of microvascular anastomoses.

Keystone is an architectural term referring to a wedge-shaped material placed on the peak central of the arcus, made to support the arch through gravity (Figure 1). The Keystone design perforator island flap was first published by Felix C Behan in 2003. It is described as “a curvilinear-shaped trapezoidal design flap”. Keystone concept is derived from Behan’s earlier work on the angiotome principle in 1975, where each angiotome may be safely raised as a flap, or extended by linkage vessels with an adjacent angiotome.²

Cutaneous perforators reach the skin by numerous different courses, either direct, through the fascial septae, fascia, muscle, or bone. The density of these vessels varies in different body areas ie. reticular dermis in the face is five times more vascularized than foot sole. This holds clinical implications in raising the flaps. Cormack and Lamberty type A flaps are usually the most common pattern for Keystone flaps. Given the universal distribution of perforators with the subcutaneous vascular support, Keystone flap is potentially suitable for all areas of the body from head to toes.⁴ The Keystone skin island is based on the randomly located perforators and there is no need to specifically identify these perforators. The advantages of this kind of perforator flap are its simple to design, robust vascular supply, a more reliable healing, shorter operative time, minimal patient morbidity, with a relatively pain-free surgery, good aesthetic outcome, and a more cost-effective wound closure.

**PATIENT AND METHOD**

From January of 2012 to March of 2013, the Keystone flap was performed in 9 patients with defects in various region of the body including the lumbar, thorax, dorsum of the foot, plantar of the foot, posterior leg, sacrum, and

![Figure 1. The keystone shape](image)

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Cause</th>
<th>Location</th>
<th>Size (cm)</th>
<th>Perforator</th>
<th>Op Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37 ds</td>
<td>F</td>
<td>Celle extirpation</td>
<td>Lumbar</td>
<td>4 x 8</td>
<td>Identified</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>24 yr</td>
<td>M</td>
<td>Malignant tumor</td>
<td>Thorax</td>
<td>10 x 10</td>
<td>Identified</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>18 yr</td>
<td>F</td>
<td>Contracture</td>
<td>Dorsum pedis</td>
<td>3.5 x 12</td>
<td>Unidentified</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>50 yr</td>
<td>F</td>
<td>Diabetic ulcer</td>
<td>Plantar pedis</td>
<td>3 x 12</td>
<td>Unidentified</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>45 yr</td>
<td>F</td>
<td>Malignant tumor</td>
<td>Cruris</td>
<td>9.5 x 7</td>
<td>Unidentified</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>47 yr</td>
<td>M</td>
<td>Pressure sore, spinal tumor</td>
<td>Sacrum</td>
<td>4 x 8</td>
<td>Unidentified</td>
<td>45</td>
</tr>
<tr>
<td>7</td>
<td>62 yr</td>
<td>M</td>
<td>Pressure sore, cerebrovascular disease</td>
<td>Sacrum, left trochanter, left calcaneus</td>
<td>10 x 12, 6 x 7, 2.5 x 2</td>
<td>Unidentified</td>
<td>120</td>
</tr>
<tr>
<td>8</td>
<td>6 mo</td>
<td>F</td>
<td>Vascular malformation</td>
<td>Posterior cruris</td>
<td>5 x 2.5</td>
<td>Unidentified</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>53 yr</td>
<td>M</td>
<td>Malignant tumor</td>
<td>Cervicofacial</td>
<td>7 x 4</td>
<td>Unidentified</td>
<td>60</td>
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<tr>
<td>Mean</td>
<td>33.2 yr</td>
<td></td>
<td></td>
<td></td>
<td>5.9 x 7.7</td>
<td></td>
<td>81.6</td>
</tr>
</tbody>
</table>

M, Male; F, female; Op, operative
and cervicofacial area. Etiology of the defects varies from diabetic ulcer, pressure ulcer, malignant tumor, joint contracture, and vascular malformation. The mean age of the patients is 33.2 years old. Four patients are male and the rest are female. The oldest patient had multiple defects due to pressure ulcer. The mean size of the defect is 5.9 x 7.7 cm. Patients’ characteristics are summarized in Table 1.

Cases
Case number 4 is a 50-year-old female with plantar chronic diabetic ulcer of the left foot (Figure 2). She had difficulty walking and was frustrated about her limited gait. The type III Keystone island flap was raised from bilateral sides of the defect. In order to preserve vascularization of the first toe, the design of the medial flap should be placed not too close with the first toe. A portion of the defect on the proximal metatarsal of the middle toe was not covered by the flap and was covered using the split thickness skin graft.

Case number 8 is a 6-month-old baby girl with capillary type vascular malformation on the posterior of her right leg (Figure 3). The size of the malformation was 5 x 2.5 cm, excised in whole up to the fascia. The defect was reconstructed with type II keystone flap.

Case number nine was a 53-year-old male with a prior excision of the lower lip due to malignancy, and reconstruction with local flaps. He underwent reexcision due to a suspected recurrence. The resultant defect was reconstructed using the type II keystone flap as illustrated in Figure 4.

RESULT
The results are summarized in Table 1. The keystone island flaps were used to reconstruct all defects in 9 patients. In two patients, the perforator were identified; at the lumbar and thoracic region. All surgeries were elective, and the mean time of surgery is 81.6 minutes. All flaps survived completely without any vascular problems, and patients were satisfied with the results.
Figure 3. Six-month-old baby girl with capillary type vascular malformation on the posterior right leg. Left: before excision. Right: one month postoperative.

Figure 4. Left: A 53-year-old male with prior history of reconstructed lower lip after malignancy excision, with keystone flap design. Center: after re-excision due to suspected recurrence. Right: The defect was closed using the keystone flap with satisfactory postoperative result.

Figure 5. Left: The red dot sign before islanding. Right: After islanding the flap.
DISCUSSION

The keystone flaps were used to reconstruct nine defects from various body parts, with 100% success rate in this case series, demonstrating its reliability. The color, texture, and sensibility of the closed defect are similar to its neighboring tissue, because the donor are also obtained from nearby tissues. After surgery, patients were relatively pain free. The reason to this, as explained by Behan, is that the circumferential division or islanding of tissue results in a partial sympathectomy of the flap. It increases the cutaneous blood flow (up to 5-fold), raises skin temperature by >2°C, and improves rest pain such as in lumbar sympathectomy. This phenomena is clinically marked by the red dot sign (Figure 5) and vascular flare in the immediate phase, while in the delayed phase the relatively pain-free postoperative period is typically experienced by the patients.

The keystone flap design, elevation and insetting were straightforward and non-complicated. The mean time of surgery is 81.6 minutes. The longest duration was 120 minutes, in 2 cases, where the surgery involved closure of 3 defects in a single surgery, and another case required STSG.

SUMMARY

The case series has shown that the keystone island flap is a versatile, reliable, and technically straightforward reconstructive method, that can be implemented from head to toe. It does not require a specific set of training or equipments, and can be performed either by an adept or expert reconstructive surgeon equally.

REFERENCES