Evaluation of versatility of superiorly based pedicled gastrocnemius myo- or myo-cutaneous flap, in upper leg defects after trauma or tumor excision; which better?

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Abstract

Purposes: The current study aimed to focus on versatility of superiorly based pedicled gastrocnemius muscle flap or myocutaneous flap either medial or lateral head, in upper leg defects after trauma or tumor excision and importance of these flaps to improve bone healing in trauma & ensure adequate safety margin in malignant tumors with minimal complications.

Patients and methods: A prospective, randomized trial was conducted to Twenty-seven patients suffering from upper leg defects after trauma or tumor excision to compare postoperative outcomes especially bone healing with the use of superiorly based pedicled gastrocnemius muscle flap covered by split thierch skin graft (Group A; 14 (51.8%)) versus myocutaneous flap (Group B; 13 (48.2%) cases), either medial or lateral head. Postoperative follow up was for 6 months.

Results: Rapid healing of tibial fracture was noticed in 8 (57.1%) cases of group A & another 8 (61.5%) cases of group B within 2 weeks after surgery & there was no flap loss apart from partial skin loss, minor hematomas or infections; All were noticed significantly more in group A; 5 (35.7%), 6 (42.9%), 4 (28.6%) cases; But in group B; one case (8%), 2 (15.4%), one case (8%) respectively (P-Value <0.05).

Conclusion: Both gastrocnemius myo- & myo-cutaneous flaps for upper leg reconstruction are considered a reliable option to ensure good safety margin in
malignant tumor cases and help bone healing in trauma cases and myo-cutaneous flaps are more safe, no Re-do & with less postoperative complications.

**Keywords:** Trauma, Malignancy, tibial defect, gastrocnemius flaps.

**Introduction:**

All major trauma centers around the world have developed standard operative procedures for the management of open fractures of lower extremity. In order to reduce the risk of non union and osteomyelitis, early vascularised soft tissue coverage is mandatory in these injuries. (1,2,3)

Muscle flap have gained wide popularity in this context since their first use by Ger (4) Muscle flaps are also suitable for coverage of open joint and exposed orthopedic implants. Muscle flaps provide good vascularity to the defect area of either soft tissues and/or bone by their excellent intrinsic blood supply and provide a good bulk that fill these defects and provide a good healthy vascular bed for skin grafting if needed. (4,5)

Early cover has been found to reduce the incidence of complication. (6) The gastrocnemius muscle flap is the workhorse of all muscle flaps for soft tissue coverage around the knee. (7)

This type I muscle flaps with their unique and independent vascular anatomy, one pedicle (sural artery) at the level of the knee joint situated close to its origin provide blood supply to the heads of the gastrocnemius muscle. These vessels arise from the popliteal artery above the level of the knee joint. Each course a few centimeters with its venae comitantes before entering the anterior aspect of the proximal muscle belly with the innervating branches of the tibial nerve. (8,9)

The fact that the size of the muscle belly, its location in the dissection field and its transfer does not adversely impair function of the limb make it an ideal flap to cover wound in the region. (10)
The aims of limb sparing for either open comminuted tibial fracture or malignant tumors in the upper one third of the leg are improvement of survival, achievement of adequate negative margins in malignant tumors and improve quality of life functionally and aesthetically. When bone is exposed either by trauma or tumor excision it is mandatory to cover these defects by bulky vascular tissue as muscle flaps to decrease incidence of osteomyelitis due to bone exposure in trauma cases and to resist radiotherapy postoperatively if needed in malignant tumor cases. \(^{(11)}\)

The unique vascularization of gastrocnemius muscle (one pedicle to each head), the bulk of the muscle belly and its presence in the operative field after that not affect function of the limb. \(^{(12)}\)

**Vascular anatomy:**

There is only one vascolonervous pedicle for each muscular head (Mathe`s and Nahai). \(^{(5)}\) composed of a sural artery (formerly gastrocnemius artery) and of one or two veins. In a certain number of cases, a secondary sural artery is present. \(^{(6-8)}\) This pedicle is protected within the popliteal fossa with little risks of injuries. It has a mean length of 4 cm with extremes varying from 2 to 5 cm. The diameter of the sural arteries is 2 to 2,5 mm on average, that of the veins is 3 to 5 mm. \(^{(9-11)}\) In most cases, the sural artery terminates into 2 branches, occasionally 3 or even 4, having a longitudinal course, in the muscle axis, just below its deep aspect and a terminal vascular distribution. \(^{(9,11)}\)

These arteries give rise to the perforating branches destined to the cutaneous plane; some anastomoses with the vascular system of the opposite gastrocnemius; some anastomoses with the vascular system of the soleus. \(^{(11,12)}\) and finally, around the distal aponeurosis of the muscle, there is a thin network of numerous blood vessels destined to the cutaneous plane. \(^{(13)}\) These vascular characteristics are the
basis of several applications on which we will elaborate later on; It is possible to safely harvest a skin paddle overlying the muscle. (3)

The additional advantage being to raise the skin length/width ratio of the leg which should not exceed 1/1 (9) or even 1,5/1 (14) Therefore, a medial gastrocnemius flap harvested with the superjacent cutaneous plane shows a skin ratio of 3,5/1 (8 cm - 30 cm); During the elevation of a myocutaneous flap, the delicate distal perifascial vascularisation should be preserved; It is possible to divide the muscle in two sections longitudinally according to the needs. (15,16) For Bashir (17) the anastomosis between medial and lateral gastrocnemius muscles allow to harvest a gastrocnemius which is vascularised by them; The large caliber of blood vessels is compatible with the creation of a “local free flap”. (7,18,19)

Patients and methods:

After local ethical committee of Benha university approval and obtaining written fully informed patients consent, This study included twenty-seven patients with exposed upper one third of tibia who were fit for surgery from Benha University during the period between July 2011 to August 2014; so as to allow 6 months follow-up period for the last case operated on. All patients presenting were admitted at General Surgery ward for clinical evaluation, laboratory assessment.

Patients included in this study were suffering from trauma; 20 (74.1%) cases with age range (21-40 years old) or malignant soft tissue tumor 7 (25.9%) cases with age Above; 45 years old; All were fit for surgery with good general condition. But, Patients were excluded from this study who were suffering from; diabetes mellitus, peripheral arterial ischemia, hypercoagulation disorders, those maintained on immunosuppressive therapy or corticosteroids, traumatic crushed gastrocnemius muscle, tumor invading this muscle or previous muscle harvesting.
Operative procedures:

In all cases of trauma; emergency operative procedures was done & was included debridment and bone fixation by external fixator; because all cases were associated with Gustilo type III fracture tibia, further debridment and preparation of wound for coverage.

Swab culture of wound was sent in all cases and any overt infection was treated 1st then flap coverage was provided after 1-4 weeks after trauma. The seven tumor cases were 3 cases of soft tissue sarcoma of the upper third of the leg and 4 cases of squamous cell carcinoma on top of old scars in the upper third of the leg proved by preoperative pathology, preoperative evaluation of the tumor extent was done by computed tomography scan also metastatic work up was done, intraoperatively wide local excision of the tumor to achieve safety margins guided by intraoperative pathology.

Harvesting techniques:

After general or spinal anesthesia; the pre-operative localization of the muscle to be harvested in an upright position, with and without muscular contractions, gives a good indication on the amount of muscle mass available which varies from one patient to another; the localization in the posterior median groove at the upper part of the leg of the subcutaneous adipose tissue containing the lesser saphenous vein and the medial sural cutaneous nerve (formerly sural nerve and vein), elements which are preserved allow to divide the 2 gastrocnemius muscles. The division of the gastrocnemius and soleus is easy to perform, and often characterized by the presence of the plantaris muscle within them; The medial gastrocnemius, longer, thicker, more movable than the lateral muscle, has a better arc of rotation, which allows it to cover the proximal 1/3 of the leg, the knee at the medial as well as lateral level, the medial distal femur. Its arc of rotation can be improved by being passed under the gracilis and semitendinosus tendons. Finally, the preservation of the aponeurosis of the leg during the dissection enables to raise a medial saphenous flap at the same time or later on. (20)
Open fracture of the proximal third of the tibia is; a. stabilized by external fixation; b. Elevation of a medial gastrocnemius flap; c. The flap is turned over the exposed tibia; d. Result at the end of the surgery; Longitudinal division of the soft tissue of the medial gastrocnemius (GM) or of the lateral gastrocnemius (GL). According to Francel et al. (11) when a tunnel has to be created within the muscle, if the skin is cicatricial, it is preferable to discard it and to use the muscle as a thin skin graft, in order to prevent the loss of the flap caused by compression; when a myocutaneous flap is elevated the “‘soaping” which may damage the perforators, should be avoided by using stitches fixing the muscle to the dermis and a careful manipulation of the flap; the cutaneous plane overlying the medial gastrocnemius can be elevated up to 5 cm from the medial malleolus. (3,21,22)

In this way, the medial myocutaneous gastrocnemius enables to cover the proximal 2/3 of the leg; there are numerous thin and long blood vessels coursing distally on the aponeurosis of the gastrocnemius muscles, beyond the muscular body and which superficially run toward the skin in several locations. This perifascial vascularisation will have to be preserved during the elevation of the myocutaneous flap it is recommended to immobilize the limb when raising an innervated flap to avoid applying tensions to the sutures; the pure muscular flap will be grafted as a thin skin graft, expanded or not according to the size, in the same step that the creation of the flap, or for cosmetic reasons, within 8 to 15 days after the phase of granulation. (21,23)

The gastrocnemius is a reliable flap in the cover of leg skin loss. However, the distal 1/3 usually remains beyond the amount of coverage it can achieve. Still numerous procedures that will be described, some «tips and tricks», which can be applied to the muscular flap (group A: 14 (51.8%) cases) or to the myocutaneous unit (group B: 13 (48.2%) cases), enable to significantly improve its mobility and its arc of rotation even possibly allowing for the cover of the whole leg segment. For medial gastrocnemius flap (better used for large defects, being more bulky), incision was made 2-3 cm, behind medial border of tibia from the popliteal fossa to
below mid-calf level. Incision was deepened to deep fascia and medial head of gastrocnemius was identified and separated from underlying soleus muscle. Distal end of the muscle was sharply divided from Achilles tendon and take care to include portion of tendinous material with the muscle belly as this improved suture holding, it then divided and separated from the lateral gastrocnemius at midline raphe. Care should be taken to avoid injury to small nerve and short saphenous vein then muscle was tunneled anteriorly to cover the defect and fixed by suturing and muscles covered by thierch skin graft (Group A) if not taken as myocutaneous flap (Group B), but if taken as myocutaneous flap, skin graft needed to cover the donor area, the skin paddle taken with the muscle ranging from (5-7) cm in width and (10-15) cm in length. Lateral gastrocnemius flap (better used only for small defects being less bulky) the common peroneal nerve need to be positively identified and safe guarded, the rest of the procedure was completed as on the medial side. Wound was closed over Suction drain and then was supported with splint. (21-23) (Fig. 1-4)

**Outcome items:**

Limb was immobilized for one week, flap checked at the 3rd postoperative day for infection or necrosis and the patient followed up inpatient for one week and outpatient monthly for 6 months to assess functional outcome i.e. any disability or effect on the bulk of the cuff was recorded. follow up of bone fractures was done by orthopedic surgeon by serial x-ray scanning.

**Statistical analysis:**

Analysis of data was done by using SPSS version 16 (Bristol university; in United Kingdom). Qualitative data will be presented as numbers and percentages and will be compared between groups using P-Value >0.05 will be insignificant but if P-value <0.05 will be considered statistically significant while P-value <0.01 will be considered statistically highly significant.

**These all data were shown in the following pictures:**
Exposed tibia and nail by trauma  

Medial gastrocnemius head harvesting

Defect with skin graft over muscle

(Fig. 1): Traumatic defect was covered with gastrocnemius muscle flap that was covered by thierch graft at the defect area & the donor area was covered primarily

Malignant ulcer  

Medial gastrocnemius flap  

Skin graft over muscle flap

(Fig. 2): Malignant ulcer (squamous cell carcinoma) at upper leg was excised leaving a large defect that was covered with gastrocnemius muscle flap with overlying thierch graft at the defect area & the donor area was covered primarily
Exposed tibia  Myocutaneous flap

Donor site was covered with thierch skin graft  Final result

Preoperative fracture tibia  Postoperative; note rapid bone healing

(Fig. 3): Traumatic fractured upper tibia was fixed by external fixator & there was overlying traumatic defect that was covered with Myocutaneous flap & the donor area was covered with thierch graft.
Exposed tibia after recurrent tumor excision  Medial gastrocnemius myocutaneous flap

Donor site was covered with thierch skin graft

(Fig. 4): Fibrosarcoma at upper leg was excised leaving a large defect that was covered with gastrocnemius myocutaneous flap & the donor area was covered thierch skin graft.

Results:

A prospective, randomized trial was conducted to focus on versatility of superiorly based pedicled gastrocnemius muscle flap (Group A; 14 (51.8%) patients) or myocutaneous flap (Group B; 13 (48.2%) patients), either medial or lateral head, in upper leg defects after trauma or tumor excision and importance of
this flaps to improve bone healing in trauma & ensure adequate safety margin in malignant tumors with minimal complications. Distributed 4 (14.8%) female & 23 (85.2%) male. Patients included in this study were suffering from trauma; 20 (74.1%) cases with age range (21-40 years old) or malignant soft tissue tumor 7 (25.9%) cases with age Above; 45 years old; None of the patients were lost to follow-up, and data collection was complete. (Tab.1, Graph. 1)

(Tab.1): Distribution of cases:

<table>
<thead>
<tr>
<th>Types of flap used</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A; Muscle flap</td>
<td>14</td>
<td>51.8</td>
</tr>
<tr>
<td>Group B; Myocutanous flap</td>
<td>13</td>
<td>48.2</td>
</tr>
<tr>
<td>Indications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma.</td>
<td>20</td>
<td>74.1</td>
</tr>
<tr>
<td>Tumors of upper ⅓ leg:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Soft tissue sarcoma.</td>
<td>7</td>
<td>25.9</td>
</tr>
<tr>
<td>*Squamous cell carcinoma.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Age in years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between; 21-40 years old; Trauma.</td>
<td>20</td>
<td>74.1</td>
</tr>
<tr>
<td>Above; 45 years old. Tumors</td>
<td>7</td>
<td>25.9</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female; (♀).</td>
<td>4</td>
<td>14.8</td>
</tr>
<tr>
<td>Male; (♂).</td>
<td>23</td>
<td>85.2</td>
</tr>
</tbody>
</table>

(Graph.1): Distribution of cases:

All trauma patients had emergency debridement and bone fixation by external fixator (Fig. 2); this debridement was preparation of wound for coverage and all patients suffering from malignancy had excision with adequate safety margin then the flap was applied with a means operative time of 2 ± 0.9; range:1.5-3 hours.
Mean blood loss was 540±115, range: 400-900ml. Most patients 22 (71.5%) required blood transfusion with a mean number of used units was 1.8 ± 0.7; range: 1-3 units. (Tab.2); No intraoperative complications or mortality was recorded.

(Tab.2): Operative data:

<table>
<thead>
<tr>
<th>Operative time (Hours):</th>
<th>Strata</th>
<th>&lt;1.5</th>
<th>11 (40.8%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5-2</td>
<td>9</td>
<td>(33.3%)</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>7</td>
<td>(25.9%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2 ± 0.9 (1.5-3)</td>
<td></td>
</tr>
</tbody>
</table>

| Blood loss (ml): | 540±115 (400-900) |
| Replacement of red cells (units): | Strata | 1 | 4 (14.8%) |
|                               |        | 2 | 16 (59.3%) |
|                               |        | 3 | 2 (7.4%) |
| Total                        |        | 1.8 ± 0.7 (1-3) |

Data are presented as means + SD & number; ranges and percentages are in parenthesis.

As regard to inpatient complications, no flap loss was recorded in any of the procedure. Minor complications as partial loss of skin graft was noticed in group A in 5 (35.7%) cases at the defect area; these cases were treated conservatively & healed by 2ry intension except 2/5 (40%) cases that needed another thierch graft at the defect area; but partial loss of skin graft was noticed only in one case (8%) in group B at the donor area that was treated conservatively. Also small hematoma was noticed in group A in 6 (42.9%) cases but only in 2 (15.4%) was noticed in group B; All these cases were treated conservatively and ended with good results; Infection was encountered in trauma cases only; 4 (28.6%) patients in group A; 3 cases at recipient sites and one case in the donor area and one case in group B at the donor site; the infection was controlled by appropriate antibiotics according to culture and sensitivity. (Tab. 3 Graph. 2)
(Tab. 3): Inpatient complications:

<table>
<thead>
<tr>
<th></th>
<th>Group A; Muscle flap</th>
<th>Group B; Myocutanous flap</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 14 cases</td>
<td>N = 13 cases</td>
<td></td>
</tr>
<tr>
<td>Partial loss of skin graft</td>
<td>5   35.7</td>
<td>1   8</td>
<td>0.022</td>
</tr>
<tr>
<td>Hematoma</td>
<td>6   42.9</td>
<td>2   15.4</td>
<td>0.036</td>
</tr>
<tr>
<td>Infection</td>
<td>4   28.6</td>
<td>1   8</td>
<td>0.028</td>
</tr>
</tbody>
</table>

(Graph. 2): Inpatient complications:

As regard to bone healing in cases of traumatic tibial fracture or bone defects due to tumor excision for adequate safety margin, there was nearly equal results between both groups i.e. rapid healing of fracture in 8 (57.1%) cases of group A & another 8 (61.5%) cases of group B within 2 weeks after surgery as compared to pre-operative period healing; (Tab. 4 Graph. 3); This was monitored by serial X-ray. (Fig. 3). Finally; overall wound healing was noticed in; 9 (64.3%) cases in group A & 12 (92.3%) cases in group B & functional outcome; no any disability was recorded with complete functions of the lower limb with minimal effect on the bulk of the cuff.
(Tab.4): Healing after 2 weeks:

<table>
<thead>
<tr>
<th></th>
<th>Group A; Muscle flap</th>
<th>Group B; Myocutanous flap</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N =14 cases</td>
<td>N =13 cases</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone healing</td>
<td>8</td>
<td>8</td>
<td>0.11</td>
</tr>
<tr>
<td>Overall wound</td>
<td>9</td>
<td>12</td>
<td>0.14</td>
</tr>
<tr>
<td>healing</td>
<td>64.3</td>
<td>92.3</td>
<td></td>
</tr>
</tbody>
</table>

(Graph.3): Healing after 2 weeks:

Discussion:

Management of compound fracture of tibia Gustilo type III, with involvement of Knee joint, present difficult problem to orthopedic and plastic surgeon. Reconstructive procedure is frequently required to cover the exposed bones or joints, to obliterate the dead space and help eradicate infection. (4)

Early cover has been found to reduce the incidence of complication. (6) The gastrocnemius muscle flap is the workhorse of all muscle flaps for soft tissue coverage around the knee. (7)

The gastrocnemius muscle flap, described by Ger R. (in 1971) as a muscle flap (13) is used in cases of exposed defects of the proximal tibia. (14)
The lateral head of the muscle, compared to the medial, is used more rarely in reconstructive surgery. The reasons for its restricted use are the size and the limited arc of rotation as well as the potential risk of peroneal nerve palsy of the muscle that might be caused by the surgical procedure itself. The medial head of the gastrocnemius muscle, which is the part mostly used, meets all requirements needed for a successful wound coverage.

This study was conducted to focus on versatility of superiorly based pedicled gastrocnemius muscle flap (Group A; 14 (51.8%) patients) or myocutaneous flap (Group B; 13 (48.2%) patients), either medial or lateral head, in upper leg defects after trauma or tumor excision; no intraoperative mortality was recorded with mean operative time of about 2 hours and blood loss of about 540±115 ml. Throughout 1st 2 weeks follow-up period; there was no flap loss apart from partial skin loss, minor hematomas or infections; All were noticed significantly more in group A; 5 (35.7%), 6 (42.9%), 4 (28.6%) cases; But in group B; one case (8%), 2 (15.4%), one case (8%) respectively (P-Value <0.05). This findings go in hand with that previously reported in literature concerning the applicability of gastrconemius myocutanous flap for reconstruction of upper leg defects irrespective the etiology of this defect; Han et al. used gastrconemius myocutanous segment obtained by intramuscular dissection of the vascular pedicle, for the reconstruction of composite and three-dimensional knee defects and found the flap survived completely, wound healing progressed smoothly without infection , hematoma or seroma and patients were satisfied with their aesthetic outcomes.

There are disadvantages associated with the application of the gastrconemius flap such as deformation of the donor area but this study revealed that no major complications in the donor areas apart of wound infection controlled with appropriate antibiotic treatment. The advantages of gastrocnemius flap favor its use as The surgical technique is relatively easy to perform and it requires less time
than free tissue transfers. Furthermore, the gastrocnemius flap provides better tissue coverage, greater stability to the knee joint.

As regard to bone healing in cases of traumatic tibial fracture or bone defects due to tumor excision for adequate safety margin, there was nearly equal results between both groups i.e. rapid healing of fracture in 8 (57.1%) cases of group A & another 8 (61.5%) cases of group B within 2 weeks after surgery as compared to pre-operative period healing; This was monitored by serial X-ray and overall wound healing was noticed in; 9 (64.3%) cases in group A & 12 (92.3%) cases in group B & functional outcome; no any disability was recorded with complete functions of the lower limb with minimal effect on the bulk of the cuff. This finding is supported by study done by Liu et al. (19) studied 65 cases underwent resection of proximal tibial osteosarcoma and reconstruction of the bone defect by prosthesis; 35 cases underwent the medial gastrconemius muscle flap transposition to reconstruct the soft tissues and the other 30 didn't and reported significantly lower rate of local complications with significantly higher functional outcome in the group of gastrconemius muscle flap transposition. Liu et al. (19) explained this good bone healing for the first time that myogenic progenitors of the MyoD lineage contribute to bone repair, giving new perspectives for treatment of fracture non-union through the optimization of myogenic progenitors proliferation, migration and differentiation. This eventually help to ensure good safety margin in malignant tumor cases and help bone healing in trauma cases.

Also Park et al. (10) used an extended medial gastrconemius muscle flap including a tendinous portion of the Achilles and a saphenous neurocutaneous flap for coverage in patient had multiple fractures with open comminuted patellar fractures that was initially managed but unfortunately, the fractured patella and overlying soft tissue became totally infected with wide necrosis requiring a complete debridement of dead tissue with removal of the patella and its tendon leaving a large bone and soft tissue defect on the knee joint and at 12 months
postoperatively, he showed complete extension, 135 degrees of flexion and grade IV knee extensor power and was able to ambulate without a walking aid.

This findings are supported also by another numerous studies that had been done to isolate progenitor cells from muscle for the purposes of bone tissue engineering, these approaches often utilize *ex vivo* gene therapy approaches where the forced expression of osteogenic Bone Morphogenetic Proteins (BMPs) in cultured myoblasts can lead to new bone formation after their subsequent implantation into experimental animals.\(^{(20)}\)

So muscle flaps in bone fractures not only bring blood supply but also give the fracture; myokines & progenitor cells which differentiate to osteocytes; this fact supports the concept of supposing muscle to act as a “*secondary periosteum*” which is able to contribute osteoprogenitors when periosteum itself is damaged.\(^{(21)}\)

**Conclusion:**

It could be concluded that both gastrocnemius myo- & myo-cutaneous flaps for upper leg reconstruction are considered a reliable option to ensure good safety margin in malignant tumor cases and help bone healing in trauma cases and myo-cutaneous flaps are more safe, no Re-do & with less postoperative complications.

**Reference:**


