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Original Article

SOLEUS MUSCLE FLAP FOR COVERAGE OF SOFT TISSUE DEFECT OF LEG

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ABSTRACT

Background
Open tibia fracture with soft tissue loss at the fracture site is and always a challenging problem for orthopedic surgeons to deal with. Soleus flap is an important option for such defects out of many other options.

Methods
Retrospective descriptive study in which twenty-one patients with open tibia fracture with soft tissue defect at fracture site requiring flap coverage were included in the study. In all 21 patients, the soleus muscle flap was done.

Results
Out of 21 patients, in 16 patients medial hemisoleus flap was done and in five composite soleus muscle flap was done. The average age of the patients was 37.8 years, and the right leg was more involved. In all patients, bone coverage was achieved. Three patients required debridement and mobilization of flap due to infective necrosis at the margin. The mean follow-up was 12 months.

Conclusion
Soleus muscle flap is a good and versatile flap for the coverage of soft tissue defects of the leg exposing bone or fracture.

Keywords: Open Tibia fracture. Soft tissue defect, Soleus flap

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INTRODUCTION

Open tibia fracture with soft tissue defect at the fracture site (Gustilo Anderson Type IIIb) is always a challenging problem for orthopedic surgeons. Complications like infection and nonunion are common if not addressed immediately.[1,2] Soft tissue coverage can be achieved by microvascular-free flaps or by pedicled local flaps. Microvascular-free flaps can provide good wound coverage but require trained surgeons, are fastidious, expensive, and are not spared from complications. On other hand pedicled flaps are less demanding technically, easily performed, do not sacrifice major vessel of the leg, and can be done by any surgeon with some training in flap surgery. An orthopedic surgeon knowing the vascular anatomy of muscles can easily perform pedicled flaps and can save limbs. There are many options for local flaps in the leg like fasciocutaneous rotational flap, sural flap, soleus flap, cross leg flap, propeller flap, and many more. Larger defects require free flap transfer for coverage when it comes to smaller soft tissue defects in the middle one-third and the middle one-third lower one-third junction wounds hemisoleus flap can be a reliable and relatively simple option.[3,4] Soleus muscle flap was first described by Tobin in 1985 and is widely used by many surgeons for coverage of the middle one-third of leg soft tissue defect.[5] Soleus muscle is a bipennate muscle with a median raphe. Its vascular supply is described as Mathes and Nahai type II and receives blood supply from the popliteal artery in its proximal part and posterior tibial artery perforators along the medial border distally and Peroneal artery perforators along the lateral border distally.[6] Soleus muscle pedicled flap is based on its vascular supply. The flap can be proximally based or distally based and can be a complete muscle flap or Hemisoleus flap. Many surgeons have used soleus muscle flap and reported its efficacy and versatility. Here in this retrospective study, we report the efficacy and our experience with pedicled proximally based soleus muscle flap in the management of soft tissue defect of middle one-third of the leg and mid-one-third and distal one-third junction of the leg.

METHODS

In this retrospective descriptive study done at B&C medical college teaching hospital and research center from April 2016 to April 2021, twentyone proximally based soleus muscle flaps were executed in 21 open tibia fractures with soft tissue defects requiring flap surgery.For this study ethical permission was taken from the institutional review board and data were collected from patient charts, operative notes, photographs, and follow-up visits.

Relevant Surgical Anatomy [7,8]

The soleus muscle is a Bipennate muscle with a median raphe located on the superficial posterior compartment of the leg anterior to the gastrocnemius muscle and originates as two heads medial and lateral from the posterior surface of the tibia and fibula. Along with gastrocnemius it forms the Achilles tendon and helps in plantar flexion of the ankle. The soleus muscle is classified according to Mathes and Nahai type II according to its vascular supply. It is supplied dominantly by the Popliteal artery and by multiple perforators from the posterior tibial artery to the medial head and perforators from the peroneal artery to the lateral head.[6,7] As it is richly supplied by many arteries at different levels from its origin to insertion, it can be safely used as a free flap, hemisoleus flap or composite flap, and reverse Soleus flap. Posterior tibial perforators can be five to eleven in number and to raise a proximally based soleus flap two to four distal perforators need to be sacrificed.[8] However maximum perforators must be saved to preserve the vascularity of muscle as some of them might have been injured during primary trauma. Gastrocnemius and soleus both are plantar flexors of the ankle, sacrificing the soleus for the flap usually does not compromise plantar flexion.

Surgical Procedure**:** All flaps raised were proximally based and we always used a medial approach to raise composite soleus flap or hemisoleus flap. Supine position with a bolster under the opposite buttocks helped in the exposure of posteromedial surface of the leg and it made easier access to the posterior compartment of the leg. A pneumatic tourniquet is always used for bloodless surgery. A longitudinal incision is placed over the medial surface of the leg one to one and a half centimeters posterior to the posteromedial border of the tibia. At times the wound is extended proximally and distally to expose the posterior compartment of the leg. The superficial and deep fascia is incised along with the skin incision. Identification of the soleus muscle is easier as it lies anterior to the gastrocnemius muscle medial head and distally it merges with the gastrocnemius to form an Achilles tendon. Another anatomical landmark is the plantaris tendon which runs in between the gastrocnemius medial head and the soleus muscle. After identification of the soleus, it is separated from the gastrocnemius. A careful meticulous and sharp dissection allows the lifting of muscle from its tendinous insertion at the Achilles tendon. Sharp dissection is usually required to prevent damage to muscular vascularity. Few distal perforators were sacrificed to gain length and maximum arc of rotation. We elevated five composite muscle flaps as the soft tissue defect was in the mid-one-third and distal one-third region and the arc of rotation and length was sufficient for the coverage; and 16 medial hemisoleus flaps for other soft tissue defects. While elevating the medial hemisoleus muscle flap the

medial head of the soleus is separated from the median raphe taking care of perforators from the posterior tibial artery and proximal release is done to gain maximum length as required for tension-free rotation. The Medial hemisoleus muscle was elevated up to the level where the arc of rotation of the flap was sufficient to cover the defect. Proximally the muscle was elevated up to mid-one-third and distal-one-third junction to preserve the adjacent perforator from the posterior tibial vessel to the flap Figure:2b. After flap elevation, it is rotated to the defect for coverage and secured around the margin of the wound with non-absorbable sutures. Scoring of soleus muscle fascia was needed whenever extra length and width of the flap were necessary. The muscle flap was then covered by a split-thickness skin graft immediately after rotation. In cases where the indwelling infection was seen skin grafting was delayed till culture sensitivity did not show any organism. Patients were admitted till the wound showed complete healing and sutures were removed. All fractures were stabilized before flap surgery. Primary debridement of the open wound was done, and fractures were stabilized with an external fixator. Flaps were performed within seven to ten days of initial surgery or fracture stabilization. Patients were readmitted for definite management of fracture after the wound has completely healed and the flap has matured.

RESULTS

Out of 21 patients, 17 (81.8%) patients were males and four (18.1%) were females. Age ranged from 15 to 59 years with an average of 37.8 years. All flaps were performed for soft tissue defects due to road traffic accidents. Follow-up ranged from six months to 20 months with an average follow-up of 13 months. All the patients were followed up for a minimum of six months postoperatively. Most defects were at the mid-one-third of the leg with seven defects being on the mid-third, distal-third junction. All wound defects were on the antero-medial surface of the leg exposing bone or fracture with a maximum wound size of 8cmX6cm (Length X Width). In 16 patients medial hemisoleus flap was done and in five composite soleus muscle flap was done. The arc of rotation of muscle flap ranged from 40° to 90° without compromising its vascularity. All flaps survived in 21 cases. In four cases skin grafting was delayed for four to six days. The first case was a case of open tibia fracture with a lacerated wound over the lateral aspect of the leg, where skin grafting was done after muscle edema subsided. Three other cases were of open tibia fractures with wound infection without any signs of osteomyelitis. In those three cases soleus flap was done which helped in controlling infection and after the culture showed no growth of the organism skin grafting was done. In one of the three cases where wound infection was seen, partial flap necrosis was observed which required debridement and secondary mobilization of the flap for coverage of the wound. Five patients had serosanguineous discharge from the wound which settled within few days without any complications. All flaps survived and served the purpose of wound coverage. We observed flap atrophy or soleus muscle atrophy at three to six months postoperative period; this resulted in a good cosmetic outcome of the wound. The average hospital stay of patients was 8 days post-flap surgery. In cases where an external fixator was applied, they required intramedullary nailing as definitive surgery after the removal of the external fixator. Nine (42.8%) patients required bone grafting after definitive surgery and the fracture healed without any further intervention.

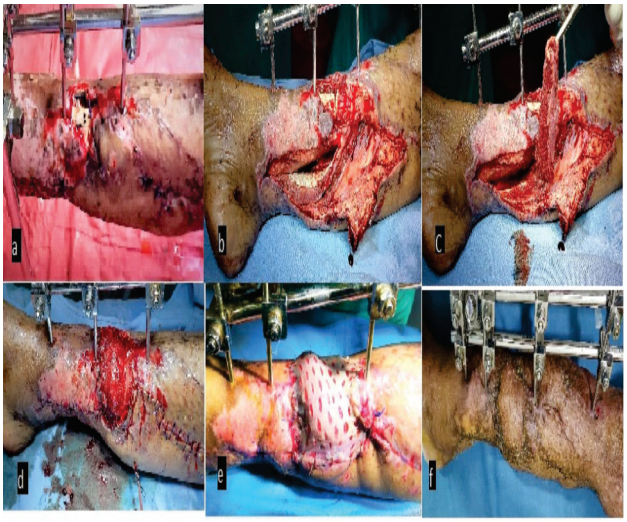

Fig.1: a. Mid1/3rd Distal 1/3rd Open Tibia fracture with soft tissue defect at fracture site after split thickness skin grafting of entire leg due to degloving injury. **b:** Debridement of fracture site with exposure of Soleus muscle. **C:** Elevation of Medial Hemisoleus. **d:** 90 degree rotation of soleus with coverage of soft tissue defect and donor site closure. **e:** Delayed Skin grafting after elemination of infection. **f:** Completely settled Flap at 8 weeks follow up.

Fig.2: a: Gustilo type IIIb open left tibia fracture at mid 1/3rd with soft tissue defect at fracture site. **b:** Elevation of soleus flap preserving the nearest perforator(arrow). **C:** Rotation of flap with coverage of defect. **d:** Suturing of flap to wound with Donor site closure. **e:** Well taken skin graft at 7 days post operative. **f:** Well settled flap with muscle atrophy giving good cosmetic appearance and complete healing of wound. **g:** Well settled flap and external fixator removal after 3 months follow up.

Table: Demographic property of patients' wounds and flap.

S. N.	Age/ Sex	Location of Defect	Etiology of Defect	Defect Size	Type of flap	Complication	Remarks
1	38/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	7cmX 6cm	Medial hemisoleus	Serosanguineous Discharge	Complete Healing
2	50/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	8cmX5cm	Medial hemisoleus		Delayed STSG + Complete Healing
3	19/M	Gustilo Type IIIb Open Right TibiaFx Distal1/3rd Mid 1/3rd	RTA	6cmX4cm	Medial hemisoleus	Serosanguineous Discharge	Complete Healing
4	44/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	7cmX5cm	Medial hemisoleus		Complete Healing
5	37/M	Gustilo Type IIIb Open left TibiaFx Distal1/3rd Mid 1/3rd	RTA	6cmX4cm	Medial hemisoleus		Complete Healing
6	15/F	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	7cmX5cm	Medial hemisoleus		Complete Healing
7	44/F	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	8cmX6cm	Medial hemisoleus	Infection with marginal necrosis	Debridement with flap readvancement Complete Healing
8	25/M	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	6cmX4cm	Complete Soleus		Delayed STSG + Complete Healing
9	59/M	Gustilo Type IIIb Open right TibiaFx Distal1/3rd Mid 1/3rd	RTA	7cmX5cm	Medial hemisoleus		Complete Healing
10	57/M	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	8cmX6cm	Medial hemisoleus	Serosanguineous Discharge	Complete Healing
11	28/M	Gustilo Type IIIb Open right TibiaFx Distal1/3rd Mid 1/3rd	RTA	6cmX4cm	Complete Soleus	Serosanguineous Discharge	Complete Healing
12	33/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	5cmX5cm	Medial hemisoleus		Complete Healing
13	18/F	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	6cmX4cm	Complete Soleus		Complete Healing
14	47/M	Gustilo Type IIIb Open right TibiaFx Distal1/3rd Mid 1/3rd	RTA	7cmX4cm	Medial hemisoleus	Infection with marginal necrosis	Debridement with flap readvancement Complete Healing
15	23/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	7cmX6cm	Medial hemisoleus		Complete Healing
16	36/M	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	8cmX5cm	Complete Soleus		Complete Healing
17	49/M	Gustilo Type IIIb open Right Tibia Fx Mid 1/3rd	RTA	7cmX 6cm	Medial hemisoleus		Complete Healing
18	53/M	Gustilo Type IIIb Open right TibiaFx Distal1/3rd Mid 1/3rd	RTA	7cmX5cm	Medial hemisoleus		Complete Healing
19	42/M	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	8cmX6cm	Medial hemisoleus	Serosanguineous Discharge	Complete Healing
20	27/F	Gustilo Type IIIb Open right TibiaFx Distal1/3rd Mid 1/3rd	RTA	7cmX4cm	Medial hemisoleus	Infection with marginal necrosis	Debridement with flap readvancement Complete Healing
21	41/M	Gustilo Type IIIb open Left Tibia Fx Mid 1/3rd	RTA	8cmX5cm	Complete Soleus		Complete Healing

(M=Male, F=Female, RTA=Road Traffic Accidents, cm=centimeters, Fx=Fracture, STSG=Split Thickness Skin Graft).

DISCUSSION

Gustilo type IIIb injuries are significantly associated with higher rates of non-unions and infections. If wound coverage is not achieved immediately infection rates can reach up to 10% to 50% and non-unions can be as higher as 20% to 60% in different literature.[1,9,10] Early coverage is associated with a predictable outcome.In one of the study the author reported that in Gustilo grade-IIIB fractures, soft-tissue coverage within (versus after) one week resulted in lower rates of infection (8% vs. 59%) and non-union (23% vs. 77%). Infection rates were lower in the early than late flap coverage group (4% vs. 50%).[11] In our series, we achieved coverage within four to seven days post-primary debridement and fracture fixation and in three (42.2%) patients' infection was seen. In another study authors also reported the infection rate in post-operative period of 17.6% which was quite similar to our study.[12] Although free flaps are considered a standard surgical procedure for soft tissue coverage of open fractures, all surgeons and hospitals are not capable of performing free flap surgeries. Often in patients with high-velocity injuries including open fractures, associated injuries like vascular injuries are present which can again limit the use of free flaps as they compromise major vessels of the lower extremity. Local flaps in the leg are limited; the soleus muscle flap has many advantages over other flaps. Soleus flap is simpler and faster to execute, it is cost-effective and eliminates the need for microsurgery.[12]In our series flaps were elevated without using loupe magnification and were elevated easily without any complications. All soleus flaps were done by orthopedic surgeons having some experience in flap surgery. All flaps survived and served the purpose of covering soft tissue defect of the leg exposing fracture of the tibia. In a review of 68 patients who underwent reconstruction with a soleus flap for soft tissue defect of the leg, the author reported a 100% flap survival rate and good to fair functional outcomes.[12]Similarly in a study done in 12 patients who underwent soleus muscle flap; author reported a 100% survival rate of flap with good functional outcomes.[13]

Most of the local flaps like rotational fascio-cutaneous flaps or propeller flaps can also fulfill the purpose but when it comes to coverage of dead space soleus muscle flap is the flap of choice in our series. In one of the study the authors also recommended using soleus muscle flap when there is a cul-de-sac to be filled.[14] We used the entire soleus muscle flap for coverage of mid-one-third soft-tissue defect in five cases as the arc of rotation of the entire soleus is sufficient in this area.(Figure:2) When the defects were more distal at mid one-third and distal one-third junction, then a medial hemisoleus muscle flap was used as it is safe to split the medial and lateral half from its raphe due to their independent blood supply and the arc of rotation of hemisoleus is longer than entire soleus muscle flap (Figure:1). In one series, 21 hemisoleus muscle flaps were done to cover soft tissue defect of the leg successfully with minimal complications.[15] In addition, the power of foot plantar flexion is preserved by the hemisoleus belly left in situ, compared to the entire

soleus.[15–18] In our series we did not find any weakness of ankle plantar flexion when the entire soleus or medial hemisoleus was used. Soleus muscle flap atrophy was observed in our series in which medial hemisoleus flap was done. A similar finding was observed by some authors in their case series.[19]

In a high-velocity injury soleus muscle may be injured. Before flap surgery surgeons should be aware of any injury to the soleus muscle and its vascularity. Surgeons doing primary initial debridement and bone fixation should assess the extent of muscle injury and make a note of it if flap surgery is anticipated. Flap tip or marginal necrosis is not uncommon. In our series, three cases (14.2%) had marginal necrosis due to infection exposing bone. They were managed with debridement and flap readvancement. Flap readvancement in a later stage was made possible by dividing the proximal-most perforator acting as a pivot point as the flap has been "Delayed" after initial flap elevation.[21]

All fractures required definitive surgery with intramedullary nailing after external fixator removal. Definitive surgery was done at three months of initial surgery after complete healing of the wound. Nine (42.8%) cases required bone grafting after six months post-definitive surgery due to nonunion. All fractures healed after definitive surgery and a few after bone grafting. Osteomyelitis was not seen in any of our cases. All limbs were salvaged, and patients were ambulatory on the injured limb after an average of four months post-injury.

The limitation of our study includes a small sample size. A large sample size would have highlighted the knowledge of flap and its uses and complications. Another limitation includes the retrospective nature of the study. The maximum follow-up of patients was 20 months, so we may not be able to produce all the long-term results of flap surgery.

CONCLUSION

Proximally based Soleus muscle flap composite or medial hemisoleus is a good and reliable option for mid-one-third and mid-one-third distal-one-third junction leg soft tissue defect. The soleus muscle flap showed its efficiency and versatility in all our cases by covering the soft-tissue defect and salvaging all the injured extremities. It is a reliable flap due to its consistent vascularity and has less donor site morbidity and complication. Orthopedic Surgeons with detailed knowledge of flap vascular supply, and muscle anatomy and with some training regarding flap elevation can easily perform soleus flap.

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REFERENCES

1. Singh A, Jiong Hao J, Wei D, et al. Gustilo IIIB open tibial fractures: An analysis of infection and nonunion rates. Indian J Orthop. 2018;52(4):406.DOI:10.4103/ortho.IJOrtho_369_16
2. Gustilo RB, Mendoza RM, Williams DN. Problems in the Management of Type III (Severe) Open Fractures: A New Classification of Type III Open Fractures. J Trauma Inj Infect Crit Care. 1984;24(8):742-746. DOI:10.1097/00005373-198408000-00009
3. Pu LLQ. Soft-Tissue Coverage of an Open Tibial Wound in the Junction of the Middle and Distal Thirds of the Leg With the Medial Hemisoleus Muscle Flap: Ann Plast Surg. 2006;56(6):639-643. doi:10.1097/01.sap.0000205-818.82084.cf
4. AlMugaren FM, Pak CJ, Suh HP, Hong JP. Best Local Flaps for Lower Extremity Reconstruction: Plast Reconstr Surg Glob Open. 2020;8(4):e2774. DOI:10.-1097/GOX.0000000000002774
5. Tobin CR. Hemisoleus and Reversed Hemisoleus Flaps: Plast Reconstr Surg. 1985;76(1):87-96. DOI:10.1097/00006534-198507000-00015
6. El Zawawy EMM, El Sekily NM. An anatomical study of the blood supply of the soleus muscle in humans. Alex J Med. 2012;48(4):315-321. DOI:10.1016/j.ajme.2012.05.001
7. Raveendran SS, Kumaragama KGJL. Arterial supply of the soleus muscle: Anatomical study of fifty lower limbs. Clin Anat. 2003;16(3):248-252. DOI:10.1002/ca.10098
8. Delgado Perez JA, Rodriguez P, Liette MD, Masadeh S. Medial Hemisoleus Flap for Middle Third of the Tibia Defects. Clin Podiatr Med Surg. 2020;37(4):621-630. DOI:10.1016/j.cpm.2020.05.001
9. Li J, Wang Q, Lu Y, et al. Relationship Between Time to Surgical Debridement and the Incidence of Infection in Patients with Open Tibial Fractures. Orthop Surg. 2020;12(2):524-532. DOI:10.1111/os.12653
10. Tielinen L, Lindahl JE, Tukiainen EJ. Acute unreamed intramedullary nailing and soft tissue reconstruction with muscle flaps for the treatment of severe open tibial shaft fractures. Injury. 2007;38(8):906-912. DOI:10.1016/j.injury.2007.02.052
11. ChuaW,De SD, Lin WK, Kagda F, Murphy D. Early versus late flap coverage for open tibial fracturesJournal of Orthopaedic Surgery 2014;22(3):294-8
12. Katelyn Kondra, Christian Jimenez, Eloise Stanton, Idean Roohani, Jake Becerra, Joseph Carey. Soleus muscle flap for reconstruction of lower extremity trauma.Workhorseor glue factory? Plast Aesthet Res 2022;9:36 DOI: 10.20517/2347-9264.2021.121
13. Il-Jung Park, Yoo-Joon Sur, Sung-Lim You. Reconstruction of the Soft Tissue defect on Anteromedial Surface of the Leg Using Medial Hemisoleus Flap.Arch Reconstr Microsurg 2014;23(2):7681.DOI.org/10.15596/ARMS.2014.23.2.76
14. Kamath JB, Shetty MS, Joshua TV, Kumar A, Harshvardhan, Naik DM.Soft tissue coverage in open fractures of tibia. Indian Journal of Orthopaedics 2012.46 (4). DOI.10.4103/0019-5413.97265
15. Pu LLQ. Further Experience with the Medial Hemisoleus Muscle Flap for Soft-Tissue Coverage of a Tibial Wound in the Distal Third of the Leg. Plast Reconstr Surg. 2008;121(6):2024-2028. DOI:10.1097/PRS.0b013e3-18171240c
16. Pu, L. L. Q. Successful soft-tissue coverage ofa tibial wound in the distal third of the leg with a medial

hemisoleus muscle flap. Plast. Reconstr. Surg. 115: 246,2005.
17. Kramers-de Quervain IA, Läuffer JM, Käch K, Trentz O, Stüssi E. Functional Donor-Site Morbidity During Level and Uphill Gait After a Gastrocnemius or Soleus Muscle-Flap Procedure: J Bone Jt Surg-Am Vol. 2001;83(2):239-246. DOI:10.2106/00004623-200102000-00012
18. Simon, S R; Mann, R A; Hagy, J L; Larsen, L J. Role of the posterior calf muscles in normal gait.. The Journal of Bone & Joint Surgery 60(4):p 465-472, Jun 1978.
19. Song P, Pu LLQ. The Soleus Muscle Flap: An Overview of Its Clinical Applications for Lower Extremity Reconstruction. Ann Plast Surg. 2018;81(6S):S109-S116. DOI:10.1097/SAP.0000000000001499
20. Ong SW, Gan LP, Chia DSY. The double muscle gastrocnemius-soleus flap in resurfacing large lower limb defects: Modifications and outcomes. J Orthop. 2020;17:13-16. DOI:10.1016/j.jor.2019.06.029
21. Cholm W. Williams, Delaying of flaps: A useful adjunct, British Journal of Plastic Surgery, Volume 26, Issue 1,1973,Pages 61-65, ISSN 0007-1226,DOI.org/10.1016/S0007-1226(73)80037-2.