Successful Limb Salvage Using an Orthoplastic Approach of Type IIIB Open Injuries of the Shoulder

A Report of 3 Cases

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Abstract

Case: We report 3 adult men (aged 28, 34, and 71 years) with successfully salvaged mangled injuries around the shoulder with high threshold for amputation. Assessment by Mangled Extremity Severity Score, Ganga Hospital Open Injury Severity Score, and Orthopaedic Trauma Association—Open Fracture Classification open injury scores predicted amputation. However, extended salvage was performed by orthoplastic approach. Two of them had superior shoulder suspensory complex (SSSC) injury. The QuickDASH score was high in 2 patients with SSSC injury and a good score in the third patient who achieved good shoulder motion.

Conclusion: "Orthoplastic approach" achieves successful limb salvage in severely mangled shoulder injuries. Volume of muscle crush injury and double disruption of SSSC injury were the main determinants of outcome.

Severely mangled open IIIb injuries of the upper limb, especially around the shoulder, may occur after high-energy road traffic accidents. Salvage of these severe injuries is a challenge, and assessment by commonly used scores such as Mangled Extremity Severity Score, Ganga Hospital Open Injury Severity Score, and Orthopaedic Trauma Association—Open Fracture Classification often predicts amputation[1-4]. Also, salvaged patients can exhibit poor results because of extensive soft-tissue crushing leading to shoulder stiffness and dysfunction[5].

Despite these problems, if the limb is salvaged, it has a better functional result with good cosmetic appearance, a psychological advantage over amputation[6-8]. Amputation is associated with persistent neuropathic pain, poor functional results, and even the best available modern upper-limb prosthesis cannot substitute the original functioning hand[6].

Salvage of mangled extremities is a highly individualized approach[9]. Extended salvage can especially be performed in upper-limb injuries where salvage has better outcome than amputation and the important requirements are availability of a dedicated anesthesia team for resuscitation and orthoplastic team approach[5]. We report 3 such cases of severely mangled IIIb injuries around the shoulder which were predicted for amputation by open injury scores, successfully salvaged with a satisfactory functional outcome. To the best of our knowledge, there are no reports in the literature about the management of major crush injuries around the shoulder.

The patients were informed that data concerning their cases would be submitted for publication, and they provided consent.

Case Reports

Case 1: A 34-year-old gentleman sustained major open type IIIb injury of right shoulder when a truck collided with a bus in which he was traveling. The size of the wound was 20 × 15 × 3 cm over the anterolateral aspect of the shoulder. Multiple rib fractures with pneumothorax and subcutaneous emphysema warranted intercostal drainage insertion.

He underwent emergency wound debridement. There was deltoid avulsion from the acromion and spine of the scapula. Severe crushing of muscle fibers resulted in loss of anterior, lateral, and middle fibers of the deltoid, loss of tendon of the long head of biceps, and partial loss of brachialis and triceps muscles. X-ray showed comminuted proximal humerus fracture with the dislocated anatomical head, displaced tuberosities, and segmental diaphyseal fracture. Acromion process and scapular body were fractured resulting in double disruption of superior shoulder suspensory complex (SSSC). Open

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Keywords: mangled IIIb shoulder injuries, limb salvage, amputation, orthoplastic approach

TABLE 1 IShowing Various Open Injury Salvage Predicting Scores Which Predicted Amputation in All 3 Cases*

Open Injury Score	Case 1	Case 2	Case 3
GHOIS	18	16	15
MESS	7	7	7
OTA-OFC	11	11	11

*GHOIS = Ganga Hospital Open Injury Severity Score, MESS = Mangled Extremity Severity Score, and OTA-OFC = Orthopaedic Trauma Association—Open Fracture Classification.

injury limb salvage scores were above the threshold predicting amputation (Table I).

We decided for extended salvage based on patient factors (no other limb injuries, good response to immediate resuscitation, no neurovascular injuries, and normal hand function) and availability of orthoplastic team approach. After meticulous debridement, osseous reconstruction was performed. The dislocated anatomical head was reduced into the glenoid cavity. Greaterand lesser tuberosities were secured to the humeral head with stainless steel (SS) wire. Proximal humerus was reduced to diaphyseal fracture and fixed with a locking compression plate. Displaced acromion process was secured to the coracoid process with SS wire. After 48 hours, a pedicled pectoralis major flap was performed to cover the critical defect (Table II).

At 18-month follow-up, the patient could use his upper limb for daily personal activities. He achieved passive shoulder abduction and forward flexion of 20°; however, rotations were restricted. He had grade 2 elbow flexion. Fractures united completely (Fig. 1), and his Quick Disabilities of the Arm, Shoulder, and Hand (DASH) score (52.3) at the final follow-up was high because of stiffness of shoulder and loss of active elbow flexion because of extensive soft-tissue loss.

Case 2: A 71-year-old man sustained injury to his right shoulder after a truck roll over accident. X-ray showed proximal humerus fracture with segmental shaft comminution, disrupted SSSC along with acromion fracture, acromioclavicular joint dislocation, open right lateral condyle of distal humerus fracture, and ipsilateral metacarpal fractures. The wound size was 20 × 15 × 3 cm. All the open injury scores were

TABLE 2 IIShowing the Details of Injury Characteristics, Soft-Tissue Cover, and Outcome*

Case No	Age/Sex	Mechanism of Injury	Muscles Injured	SSSC Injury	Neurovascular Injuries	Skeletal Injuries	Associated Injuries	No of Procedures	Type of Soft-Tissue Cover	Duration of Follow-up	Quick DASH Score
1	34/M	Side impact collision of a truck and bus	Complete deltoid loss, long head of biceps, triceps, and brachialis	Yes	No	Proximal humerus fracture dislocation, segmental fracture of the humerus shaft, acromion fracture, and body of scapula fracture.	Pneumothorax, multiple rib fractures, and subcutaneous emphysema.	2	Pedicled pectoralis major flap	18 months	52.3
2	71/M	Truck roll over accident	Loss of anterior and lateral deltoid fibers	Yes	No	Head splitting proximal humerus, segmental fracture of the humerus shaft, AC joint dislocation, and acromion process fracture	Lateral condyle fracture ipsilateral distal humerus, 1st and 2nd metacarpal fracture ipsilateral hand	2	Skin graft	12 months	79.5
3	28/M	Side impact collision of a bus and lorry	Deltoid partial loss	No	No	Glenoid neck fracture, avulsion fracture of the acromion, and proximal humerus fracture with diaphyseal extension.	Nil	2	Pedicled latissimus dorsi flap	24 months	11.4

*DASH = Disabilities of the Arm, Shoulder, and Hand, and SSSC = superior shoulder suspensory complex.

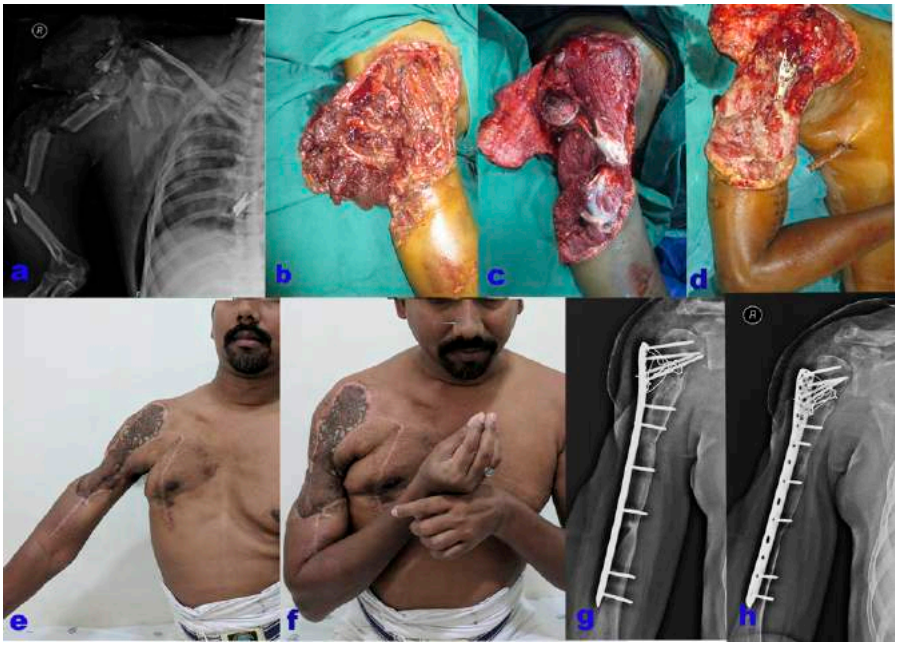

Fig. 1

A severely mangled injury of the right shoulder with grossly comminuted fractures involving both proximal and shaft of the humerus along with fractures of the acromion, spine, and body of the scapula (**Fig. 1-A**). Open wound shows avulsion of clavicular and acromial origin of the deltoid muscle (**Fig. 1-B**). Postdebridement picture showing dislocated humeral head lying within the fibers of the deltoid (**Fig. 1-C**). Large soft-tissue defect after fixation (**Fig. 1-D**) covered with the pedicled pectoralis major flap. The limb was salvaged successfully (**Figs. 1-E through 1-H**).

above the threshold for amputation (Table I). Considering good response to resuscitation, good hand function with intact neurovascular structures, salvage was considered. After resuscitation, debridement, acromioclavicular joint fixation with SS wire was performed. There was loss of anterior and lateral deltoid muscle. The humeral head was found to be split into 2 halves, which was reduced and stabilized with cancellous screws. Greater and lesser tuberosities were secured to the head and shaft with SS wires and fixed with a locking plate. Open wound required a skin graft.

At 1-year follow-up, 25° of active shoulder abduction and 60° of forward flexion were achieved. The patient developed pain and stiffness of the shoulder, elbow, wrist, and fingers with signs of type 1 post-traumatic complex regional pain syndrome (CRPS) requiring rigorous physiotherapy. Final follow-up radiographs showed complete union of the fracture (Fig. 2), and the QuickDASH score was 79.5.

Case 3: A 28-year-old man sustained severe open right proximal humerus fracture with segmental comminution of the diaphysis, glenoid neck fracture, and avulsion fracture of the acromion in a major side impact collision of a bus and lorry. The open wound size was 25 × 20 × 3 cm extending from the shoulder to middle third arm with intact neurovascular structures. Debridement and fixation of the fracture was performed. There was no double disruption of the SSSC. Pedicled latissimus dorsi flap cover was performed for the soft-tissue defect. At 2-year follow-up, the patient achieved complete union of fracture, a near-complete range of motion in the shoulder, and returned to his original duties (Fig. 3). The QuickDASH score was 11.4 at the final follow-up.

Discussion

Complex mangled injuries are usually associated with significant bone and soft-tissue damage which makes the salvage more difficult. Sometimes, they can be associated with life-threatening systemic injuries also which requires resuscitation. It is possible that they can result in poor functional outcome despite salvage[10]. There are very few studies reported in the literature about the management of severely mangled injuries of the upper limb. The main objective is to salvage the limb and to provide a cosmetically acceptable and functioning limb[11].

All the 3 patients salvaged in our study had severe crushing of soft tissues around the shoulder with intact neurovascular structures and good function of the hand. Assessment and proper decision-making on day 1 is utmost important to prevent unnecessary procedures and secondary amputations. Assessment by all the commonly used open injury scores predicted amputation in all these patients. However, an extended salvage option was chosen in all of them considering the fact that results of upper-limb injuries are better with salvage. We achieved satisfactory functional outcomes, and all of them are very much satisfied with salvaged upper limbs. In our institution, we follow the "orthoplastic approach" in the management of all open injuries where plastic surgeons are involved in open injury care from the day 1 of injury during initial debridement followed by skeletal fixation and early soft-tissue cover[12]. It was evident clinically in our patients that adequacy of debridement and "orthoplastic approach" were more important for a successful salvage and to prevent infection[12,13].

Fig. 2

A 71-year-old gentleman presented with a severely mangled right shoulder, open wound exposing crushed anterior deltoid, intermediate deltoid fibers and proximal humerus articular surface (**Figs. 2-A and 2-B**). Radiograph showing head split proximal humerus fracture and segmental comminution of the humerus shaft (**Fig. 2-C**). The soft-tissue defect required split-skin grafting. The patient achieved complete union of all the fractures, and the limb was salvaged successfully (**Figs. 2-D and 2-E**).

Primary plate fixation provides adequate stability in upper-limb open injuries[7]. All the 3 patients had plate fixation for extensive comminution of proximal humerus with fracture extending up to diaphysis. Double disruption of SSSC makes the joint unstable[14], and 2 of our patients had double disruption and underwent reconstruction with SS

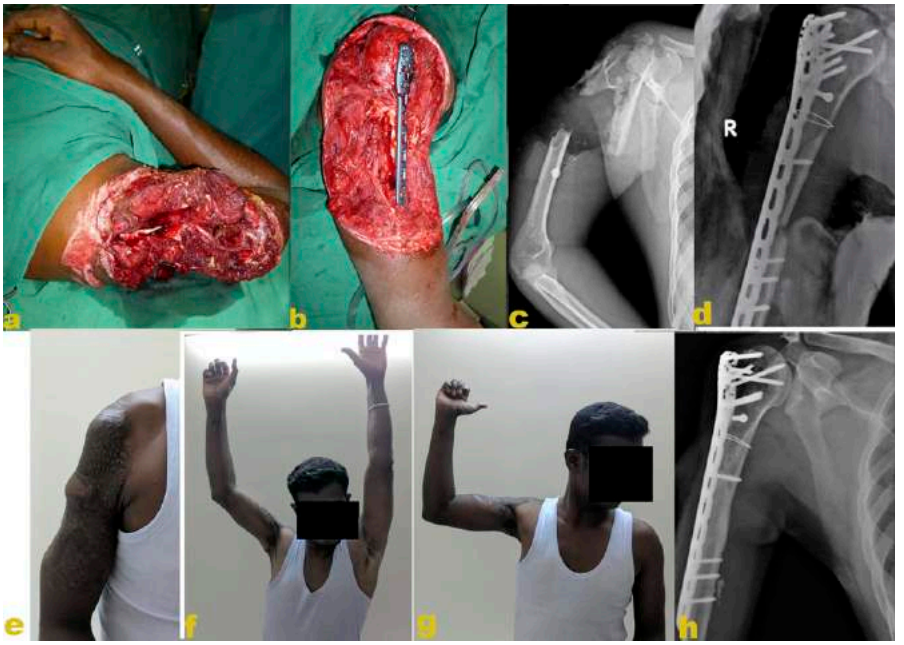

Fig. 3

A 28-year-old male patient presented with a major open injury of the right shoulder (**Fig. 3-A**), comminuted segmental proximal humerus fracture along with intact superior shoulder suspensory complex (**Fig. 3-B**). After immediate debridement, locking plate fixation of proximal humerus fracture followed by flap cover was performed (**Figs. 3-C and 3-D**). At 2 years of follow-up, the patient achieved satisfactory shoulder function and complete union of proximal humerus fracture (**Figs. 3-E through 3-H**).

wires. None of our patients developed postoperative infection.

Soft-tissue cover of open wounds must be performed as soon as possible to avoid complications such as infection, nonunion, and muscle necrosis. The "fix and flap" protocol advocates wound cover within 72 hours of injury. This led to a decrease in deep infection rates to as low as 6%[12,15]. Pedicled latissmus dorsi and pectoralis major flaps provide good coverage for large shoulder defects[16]. Two of our patients required pedicled flap cover while one required only SSG. In all cases, coverage was performed within 72 hours.

Groh et al. have reported in their study of 33 patients that anterior deltoid is the most important and irreplaceable muscle of the shoulder[17]. In cases 1 and 2, despite good radiological outcome and no infection, both could achieve only limited shoulder movements, and this can be attributed to the severity of soft-tissue injury and double disruption of SSSC. In case 1, severe crushing of muscles resulted in a near-complete loss of anterior, lateral, and posterior fibers of the deltoid, loss of the long head of biceps, and partial loss of humeral origin of biceps and brachialis muscle fibers resulting in restricted shoulder movement and loss of active flexion of the elbow. In case 2, a complete transection of deltoid from origin resulted in the loss of anterior and lateral deltoid. Despite supervised physiotherapy, he developed features of type 1 post-traumatic CRPS grossly affecting his functional outcome.

At the final follow-up, fractures in all the 3 patients had united without any requirement of secondary procedures. There were no signs of avascular necrosis (AVN) of the humeral head. Lee et al. in his study of 19 patients with displaced proximal humerus fractures concluded that the majority of them develop AVN, but most revascularize with creeping substitution[18].

Conclusion

"Orthoplastic approach" achieves successful limb salvage in severely mangled shoulder injuries. The main determinants of outcome are the volume of muscle crush injury and double disruption of SSSC injury. ■

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References

1. Rajasekaran S, Babu JN, Dheenadhayalan J, Shetty AP, Sundararajan SR, Kumar M, Rajasabapathy S. A score for predicting salvage and outcome in Gustilo type-IIIA and type-IIIB open tibial fractures. J Bone Joint Surg. 2006;88(10):10.

2. Parikh S, Singh H, Devendra A, Dheenadhayalan J, Sethuraman AS, Sabapathy R, Rajasekaran S. The use of the Ganga Hospital Score to predict the treatment and outcome of open fractures of the tibia. Bone Joint J. 2019;102-B(1):26-32.

3. Johansen K, Daines M, Howey T, Helfet D, Hansen ST. Objective criteria accurately predict amputation following lower extremity trauma. J Trauma. 1990;30(5):568-72.

4. Orthopaedic Trauma Association: Open Fracture Study Group. A new classification scheme for open fractures. J Orthop Trauma. 2010;24(8):457-64.

5. Brown JB, Cannon B. Repair of major defects of the arm by combination of plastic, orthopedic and neurologic surgical procedures. Trans West Surg Assoc. 1948;54:212-5.

6. Tintle SM, Baechler MF, Nanos GP, Forsberg JA, Potter BK. Traumatic and trauma-related amputations: Part II: upper extremity and future directions. J Bone Joint Surg Am. 2010;92(18):2934-45.

7. Bumbasirevic M, Stevanovic M, Lesic A, Atkinson HDE. Current management of the mangled upper extremity. Int Orthop. 2012;36(11):2189-95.

8. Graham B, Adkins P, Tsai TM, Firrell J, Breidenbach WC. Major replantation versus revision amputation and prosthetic fitting in the upper extremity: a late functional outcomes study. J Hand Surg. 1998;23(5):783-91.

9. Miller EA, Iannuzzi NP, Kennedy SA. Management of the mangled upper extremity: a critical analysis review. JBJS Rev. 2018;6(4):e11.

10. Mitchell SL, Hayda R, Chen AT, Carlini AR, Ficke JR, MacKenzie EJ, et al The military extremity trauma amputation/limb salvage (METALS) study: outcomes of amputation compared with limb salvage following major upper-extremity trauma. J Bone Joint Surg Am. 2019;101(16):1470-8.

11. Devendra A, Velmurugesan PS, Dheenadhayalan J, Venkatramani H, Sabapathy SR, Rajasekaran S. One-bone forearm reconstruction: a salvage solution for the forearm with massive bone loss. J Bone Joint Surg. 2019;101(15):e74.

12. Gopal S, Majumder S, Batchelor AG, Knight SL, De Boer P, Smith RM. Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia. J Bone Joint Surg Br. 2000;82(7):959-66.

13. Okike K, Bhattacharyya T. Trends in the management of open fractures. A critical analysis. J Bone Joint Surg Am. 2006;88(12):2739-48.

14. Oh C, Jeon I, Kyung H, Park B, Kim P, Ihn J. The treatment of double disruption of the superior shoulder suspensory complex. Int Orthop. 2002;26(3):145-9.

15. Shanmuganathan R, Agraharam D, Perumal R, Jayaramaraju D, Chandramohan AK. In: Tornetta P, Ricci WM, Ostrum RF, McQueen MM, Mckee MD, Court-Brown CM, eds. Initial Management of Open Fractures In Rockwood and Green's Fractures in Adults. 9th ed. Philadelphia: Wolters Kluwer; 2019:811-80.

16. Dowden RV, McCraw JB. Muscle flap reconstruction of shoulder defects. J Hand Surg. 1980;5(4):382-90.

17. Groh GI, Simoni M, Rolla P, Rockwood CA. Loss of the deltoid after shoulder operations: an operative disaster. J Shoulder Elbow Surg. 1994;3(4):243-53.

18. Lee CK, Hansen HR. Post-traumatic avascular necrosis of the humeral head in displaced proximal humeral fractures. J Trauma. 1981;21(9):788-91.