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Research Article

Subtrochanteric Non-Union - Failure to Function

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Abstract

Objective: To introduce Ten Commandments for management of Subtrochanteric Non-union.

Design: Prospective study of 56 patients treated from January 2018 to December 2023. All 56 patients were managed by following "Ten Commandments "postulated to give consistent results in subtrochanteric non-unions. Aim was to achieve anatomic reduction, absolute stability, compression at fracture site, stimulation of biology, eradication of infection (if present), soft tissue coverage. Regular follow up for wound healing, fixation failure, infection control, healing of non-union done with minimum follow up for 24 months.

Setting: Multicentetic

Patient Selection Criteria – Patients between 18 to 60 years with subtrochanteric non-union (Septic & Aseptic) included with minimum follow-up of 24 months. Patients with non-unions of pathologic fractures, chronic kidney & liver disease excluded.

Outcome Measures and Comparisons - Functional assessment done by Parker Mobility Score (PMS).

Results: "Ten commandments" introduced in this study takes care of all the mechanical and biological factors responsible for non-union. PMS in all patients were encouraging. All patients reached the pre-injury level of activity. No patient had limp, deep vein thrombosis, osteonecrosis,

Conclusions: "Ten commandments (PEEDACASSS)" paves the way for managing subtrochanteric non-union with predictable results. Biology and mechanical interplay need to be set at a tune to lead bony union. Debridement, reconstruction of medial pillar and shingling being the most critical steps.

Level of Evidence – Level II

Keywords: *Subtrochanteric non-union, Ten commandments, PEEDACASSS,*

Introduction

Subtrochanteric non-union is not only a failure of healing of bone, but of a complex interplay between biology, mechanics, and surgical intervention. This complication transforms a common injury into a debilitating condition, marked by persistent pain, profound disability, and the daunting prospect of complex, high-stakes revision surgery. Non-union rates for subtrochanteric region are as high as 7% to 34%.[1] This stark figure highlights the inherent difficulties in managing these injuries and its profound impact on healthcare system. Non-union is an irreversible stage in the cascade of fracture healing devoid of all potentials of regeneration.[2]

Non-union of subtrochanteric fracture reflects either inadequate stability or poor biology or both. Subtrochanteric zone is the most highly stressed zone of the body, the level of stress can go up to six times of body weight.[2] Thick cortical bone, tenuous blood supply, cantilever anatomy of head and neck with high unequal biomechanical stress, compressive forces on posterio-medial cortices more by 20% as compared to the tensile surface creating varus tendency, cortico-cancellous junction make the fractures of this zone more susceptible to non-union.[3] Implant failure is a consequence, not a cause of non-union. Failed post osteosynthesis non-unions following once/multiple surgical interventions is challenging due to previous fibrous and scar tissues, osteoporosis, compromised vascularity of bone and soft tissues, dormant infection, and presence of the failed implant. Post-surgical causes for non-union are mainly loss of initial reduction—varus or procurvatum, misplaced implant, wrong entry point, excessive soft tissue stripping, and selection of the wrong implant. The various procedures tried to treat non-union after nailing are dynamization of nail, exchange nailing, bone grafting, augmentative plating, nail conversion to the plate or prosthetic replacement. The length of the proximal fragment, deformity, bone defect, bone stock, age, presence of implant, and surgeon's preference help in decision making.[4] The healing time is more in non-unions hence the implant has to bear stresses for a longer duration of time. Moreover, the earlier failed implant is indicative of a slower pace of healing than stress accumulation on the device leading to failure. Osteo-periosteal decortication and cancellous bone graft re-initiates and expedites the process of fracture healing.[5] The "Diamond Concept" clearly gives importance to both mechanical and biological factors in addressing associated comorbidities.[6] Physiology works in stable anatomical conditions otherwise it becomes pathological.[5] With all clearances, informed. This article aims to lay down evidence-based commandments which will illuminate the path from failed fracture to a successful recovery.

Methods

It's a prospective study of 56 patients treated between January 2018 to December 2023. Ethical clearance was obtained from the institutional ethical committee. Out of 56 there were 38 males and 18 females between 34 to 64 years. 41 patients had aseptic non-union and 15 patients had infected non-union. They reported for pain around the thigh, inability to bear weight, shortening. Infected non-union patients have discharging sinuses with other symptoms. All patient underwent a detailed history session since the first episode and clinical examination. Clinical (Pain, inability to bear weight, redness, local warmth) radiological (lysis around implant, bone resorption, sequestrum, involucrum) and haematological parameters (CBC, ESR, CRP) of infection evaluated.

Inclusion & Exclusion Criteria

Patients between 18 to 60 years with subtrochanteric non-union (Septic & Aseptic) included with minimum follow-up of 24 months. Patients with non-unions of pathologic fractures, chronic kidney & liver disease excluded.

Surgery planned after physical fitness for surgery, written informed consents and all ethical clearances. All surgeries were performed by the corresponding author. All patients were operated in spinal anaesthesia in lateral position with affected side up.

1. Operative Technique – Ten Commandments (PEEDACASSS)

Position: Lateral decubitus position with affected side up on a radiolucent table is the position of choice. All bony prominences were padded with support from both sides. Affected extremity prepped and draped to allow free movements intra-operatively. A pillow is kept in between kness.[7] Anterior superior iliac spine (ASIS) and greater trochanter (GT) marked. (Figure 1)

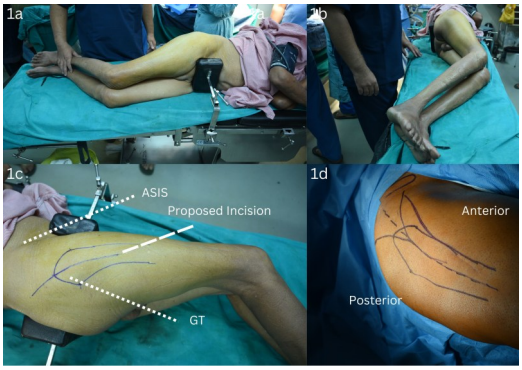


Figure 1 (a to d) *– 1a &1b - lateral decubitus position of patient. 1c & 1d – showing skin marking of GT & ASIS with proposed incision.*

2. Exposure: Incision is centered over GT with 1/3 extension proximally and 2/3 extension distally along the shaft. Skin & subcutaneous tissue separated and haemostasis achieved. Iliotibial band incised along the incision and vastus lateralis exposed. Vastus lateralis can be lifted up to expose underlying non-union site.

3. Extraction of previous implant: IM & EM implants are taken out in atraumatic manner. Foot prints of surface implant are debrided. Broken and damaged implant removal set must be ready as extraction becomes challenging if nail, plate or screws are broken or cold-welded.

4. Debridement: Debridement form the critical part of surgery especially in infected non-union. Absolute debridement both IM & EM done. Sequestrum and involucrum taken out. IM reaming and lavage done. No suspicious tissue left. Sinus tracts traced and excised. Tissue from non-union site and suspicious infected material collected to be send for tissue culture and antibiotic culture sensitivity. Once the debridement completed, IM & EM copious lavage with 6 litter irrigation fluid (Normal Saline, Povidone Iodine, Hydrogen Peroxide, Vancomycin) given. Absorbable calcium phosphate beads with antibiotics (Vancomycin 4gm) used to get maximum antibiotic concentration at the infection site.

5. Antibiotic Delivery (IM & EM): To control infection stability is needed. All patients with infected non-union had antibiotic coated (Vancomycin 4gm in 40 gm bone cement) Kuntscher-nail. This achieves high IM antibiotic concentration. Absorbable calcium phosphate bead provides high EM antibiotic concentration. The nail was kept for minimum of three months or till clinical, radiological and haematological marker of infection shows normalancy for consecutive three readings with a gap of a month.

6. Contact: Achieving bone to bone contact especially on medial cortex is the most yielding factor for the bone union. As little as 2 mm of separation would lead to medial collapse and lateral plate bending and failure of implants.[8] Subtrochanteric region has tremendous deforming forces and high stresses leading to implant failure before union occurs hence need bone to bone transfer. Reconstruction of medial pillar is done in all cases. In case of medial void, it was filled with bone graft to ensure medial cortical continuity.

7. Alignment: Length, rotational alignment, angulation corrected. Varus position of proximal fragment is corrected and it was aligned in valgus with distal fragment. Mal-reduction in any plane more than 10 degrees hampers the weight transfer and healing process.[9]

8. Stability: Absolute stability is aimed at nonunion site. In this study combination of IM & EM device is used in all cases. Long proximal femoral nail with single hip screw was the preferred choice for IM fixation. For EM fixation proximal femoral hook plate, 4.5 mm narrow dynamic compression plate is preferred. IM nail locked with 2 distal interlocking bolts. EM plate is spanned from tip of GT to at-least 6 cm from non-union site distally. Hook plate is locked with at-least 2 screws in oblique direction to increase their pull-out strength. All attempts to achieve compression at fracture site done. Inter-fragmentary screw placed wherever nonunion planes allows. (Figure-2)

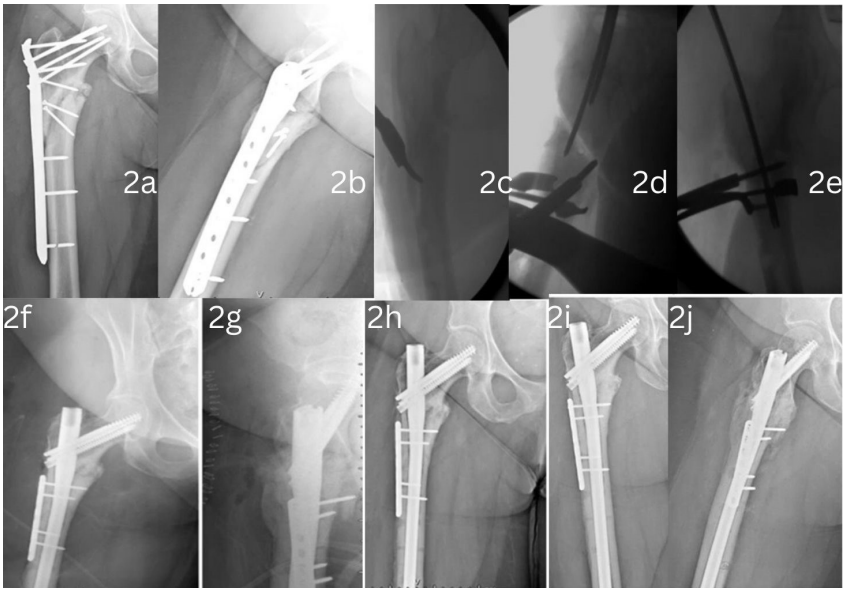


Figure 2 (a to j) *- 2a & 2b – 14 months old aseptic non-union. 2c, 2d & 2e – Intra-op steps of reduction and IM reammings. 2f & 2g – Post-revision X rays. 2h – 6 weeks post-revision. 2i – 14 weeks post-revision. 2j- 6 months post-revision.*

9. Stimulus: Shingling is done in all cases to reactivate the healing process. Bone graft (Autogenous or allograft) added for osteogenic & osteo-inductive properties and sometime as a structural support. Shingling is done 360 degrees 2 cm proximal and distal to non-union site to raise osteo-periosteal flap. Autogenous grafts were harvested from ipsilateral iliac crest. (Figure-3)

10. Soft tissue cover: In infected nonunion debridement might result in tissue loss requiring vacuum assisted closure (VAC), skin grafting, sometimes rotation flap. Careful & complete debridement done without having any dead space or defect (Figure-4). VAC is used in some of the non-infected cases for rapid wound healing.

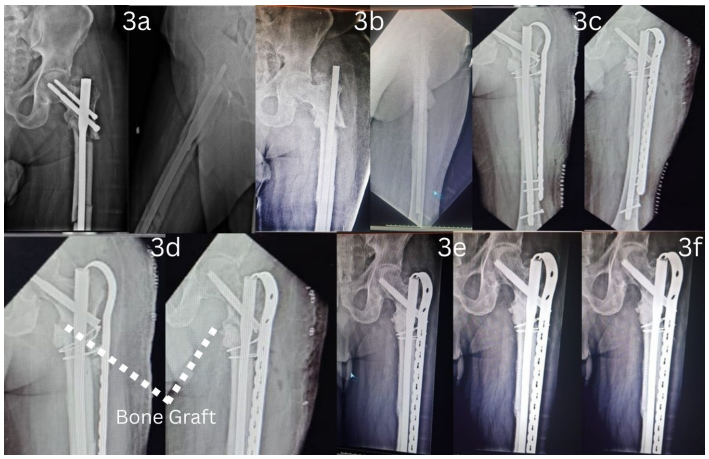


Figure 3 (a to f) – *3a - 10 months old infected non-union. 3b – Showing antibiotic coated nail. 3c – post-revision X rays. 3d – Showing BG filled in the medial void. 3e – 8 weeks post-revision. 3f – 15 weeks post-revision.*

Figure 4 (a to d) *– 4a – Showing soft tissue defect with discharging sinus in an infected subtrochanteric non-union. 4b & 4c – Showing wound healing after wound debridement. 4d – X-ray of same patient.*

Post-operative protocol

Ankle pumps, quadriceps, hamstring exercises started as soon as anaesthesia weaned off. Bed side sitting and walking non-weight bearing (NWB) commenced next day. High risk patients with co-morbidities received oral Apixaban 5 mg given for 6 weeks. Patient counselled to refrain from tobacco and smoking. Patients mobilized tip toe weight bearing with walker for 2 months. Full weight bearing commenced after 2 months. During this time the patients monitored for radiological & clinical signs of healing. Minimum follow up of 24 months is observed. Reborne Bone Healing Score used for radiological consolidation (Table 1).[10]

Table 1 - Reborne Bone Healing Score	
Cortical Score	**Stage**
0	Non-interpretable/non-visible. Hidden by plate
1	Fracture unchanged
2	Callus present but not continuous
3	Callus continuous but fracture still visible
4	Callus with same density as cortex

Regular follow up for 24 months done to observe for wound healing, fixation failure, deep vein thrombosis (DVT), fracture union, osteonecrosis, infection and other complications. Parker mobility score[11,12] (PMS) used for functional assessment (Table 2)

Table 2 – Parker Mobility Score (0-9)	
Able to get about the house	No difficulty (3) With an aid (2) With help from another person (1) Not at all (0)
Able to get out of the house	No difficulty (3) With an aid (2) With help from another person (1) Not at all (0)
Able to go shopping	No difficulty (3) With an aid (2) With help from another person (1) Not at all (0)

Results

PMS recorded and used as functional outcome. (Figure-5) Comparative analysis of pre-injury, pre-revision & post-revision shows remarkable improvement. One patient had discharging sinus and limp for almost 6 months. Out of the 15 infected patient, 4 Klebesiella Pneumoniae, 3 Escherichia Coli, 3 Staphyloccus aureus, 2 Klebesiella Aerogenes, 1 Psudomonus, 2 showed fungal growth on culture. Rest of the 41 patients had negative culture and insignificant histopathology report. Reduction and implant hold their position till the union. "Ten commandments" followed in this study resulted in excellent outcome and appears to take care of all the factors responsible for the pre-revision condition.

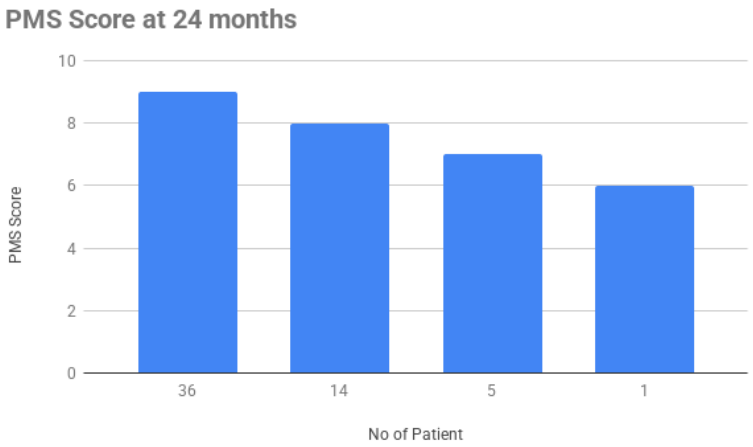


Figure 5. *Showing PMS score at 24 months.*

Discussion

While undertaking this study the inclusion criteria were extensively discussed and arrived at a conclusion that, fractures with a gap of 9 months from index surgery without any radiological evidence of union or non-progressive reparative status for last three consecutive months, failed implant at any point of time to be included. Dormant infection was another standpoint of discussion so apart from clinical, radiological & haematological criteria, it was decided to send the culture and histopathological sample for every patient. Ten commandments postulated in this study take care of mechanical and biological parameter required for bone healing.

Operating position is important factor which allows execution of your planning. Though lateral position requires some manipulation for perfect antero-posterior and lateral view intraoperatively its following benefit overcomes this concern.

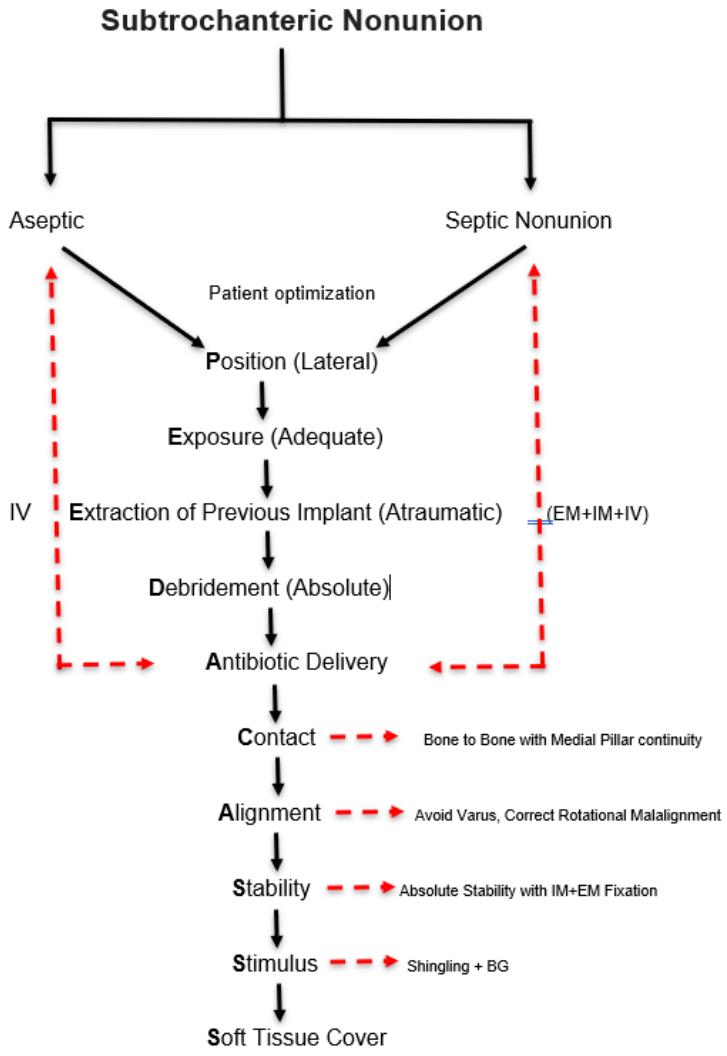
- Good all-around access to hip and shaft
- Gravity assisted reduction helpful in obese patient
- Ease of exposure
- Better intra-op manipulation and reduction
- GT becomes prominent which helps in proper entry point for IM nails.
- Adjuvant extra-medullary (EM) plate application becomes easy.
- Iliac crest for graft harvestation in easy.

Proper exposure is crucial for each step of execution of revision procedure including removal of previous implant, debridement, reduction, fixation. 360-degree access to non-union site helps specially in infection and also in shingling. Extraction of previous implant and their foot print will aid in controlling infection. Debridement needs to be absolute at non-union site and also towards suspicious infectious tissue but with the caution to not to create a dead space. Debridement reduces bacterial burden, eliminates biofilm, creates a healthy wound bed, promotes healing, facilitates antibiotic penetration. Debridement can be surgical, mechanical, biological, enzymatic, ultrasonic. The DIME approach to chronic wound management is a global concept approach from which a more detailed pathway can be initiated to bring about wound resolution.[13] Bone destruction caused by infection is due to the dysfunction of various systems. One of the important factors in bone destruction is increased bone resorption by excessive osteoclast differentiation and proliferation. Osteoclasts can phagocytose but are not capable of killing the bacteria. As a consequence, bacteria persist in osteoclasts over long tie periods, which promotes the bone resorption process.[14] Local antibiotic delivery achieves therapeutic levels of antibiotics directly at the infection site in high concentration is necessary to eradicate infection. It reduces systemic toxicity, overcomes bioavailability issues and improve patient compliance. In this study EM antibiotic delivery by beads and IM antibiotic delivery done with antibiotic impregnated nail. In addition to local drug delivery, it also gives stability till the infection is controlled. Sensitive drug (antibiotic, antifungal, antiviral) given intravenous for 6 weeks followed by oral for another 3 weeks. Haematological parameters CBC, ESR, CRP evaluated every month. A non-responding trend is a indication to re-search for causative organism. A normal haematological parameter for consecutive 3 months is an indication of infection control and definitive fixation can be planned at this stage.

Bone healing is a repair process of a mechanical discontinuity loss of force transmission, and pathological mobility of bone.[15] Through a sequence of changes of tissue development and geometry, the original structural integrity is restored. The recovery of rigidity and strength is related to tissue differentiation. Absolute stability at non-union site ensures a predictable complex interplay of physical and biological factors. The different patterns of bone repair respond to physical influences including strain tolerance. Subtrochanteric area is under tremendous forces passing across it. Compressive forces on medial side and tensile forces on lateral side. Until unless there is bone to bone contact between proximal & distal fragment especially on medial and posteromedial cortex, healing process will not proceed. No matter how strong the implant is, implant failure is inevitable. Reconstruction of medial pillar is perhaps the most yielding point in subtrochanteric region surgeries. Subtrochanteric region also have many deforming forces acting together.

Varus correction and medial cortical apposition forms the mainstay of intraoperative manipulations. Once these objectives are achieved then it's the fixation stability which will sail the ship. In this cohort combination of IM & EM fixation is used as it gives the best biomechanical stability. Long proximal femoral nail with single screw / blade or an InterTAN type screw was preferred with locking from the top and two distal interlocking bolts. This IM fixation augmented by EM fixation with either hook plate or dynamic compression plate. Screws through the plate were oriented either perpendicular to plane or in a oblique fashion so as to increase its pull-out strength. Shingling all around non-union site 2 cm above and 2 cm below done to raise the osteo-periosteal flap so as to activate healing process.

Autogenous bone graft from ipsilateral iliac crest is used on non-union site and tricortical bone graft was used to achieve medial cortical continuity in case of medial void. Ideal soft tissue cover can be defined as well vascularized, space filling, preferably sensate, epithelialized tissue that is soft, not fibrotic, robust and stable, covering bone and metal implants with optimal function and cosmetic appearance.[16] The objective is to provide a robust barrier preventing further bacterial contamination of the fracture site and a biological environment conducive to fracture healing and eradication of infection whilst not getting in the way of a good functional outcome. Ten commandments are the systematic way of tackling this difficult problem with taking mechanical and biological factors in to consideration. See Flow Chart (Fig-6)



Flow Chart 1 – Showing sequence of application of Ten Commandments

Limitation of Study

A small cohort of patients, no other comparative study

Conclusions

"Ten commandments (PEEDACASSS)" paves the way for managing subtrochanteric non-union with predictable results. These commandments set the biology and mechanical interplay at a tune to lead bony union. Debridement, reconstruction of medial pillar and shingling being the most critical steps.

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