Case Report

Retrograde femoral nails for emergency stabilization in multiply injured patients with haemodynamic instability

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ABSTRACT

Introduction: The purpose of this study is to retrospectively evaluate the immediate effect of retrograde intramedullary femoral nail (RIMFN) fixation technique on patient's hemodynamic status as documented by vital signs (blood pressure and pulse) intraoperatively in all patients with femoral shaft fractures with multiple injuries and hemodynamic instability who were treated with RIMFN at our institution on emergency basis as part of damage control orthopaedics.

Patients and methods: A retrospective review of intra operative vital signs obtained from patient records was completed at a Level 1 trauma center in a university hospital.

In all, 11 multiply injured patients with (14) femur fractures with hemodynamic instability were identified. Of those, 3 had bilateral femur fractures. Closed reduction and retrograde femoral nailing without proximal locking was performed to achieve immediate skeletal and haemodynamic stability. Pulse rate and BP measurements were noted for all patients starting from the time patient would enter the operating room till the patient was shifted back to the recovery ward.

Results: The average cohort age was 28 years (20–36 years). The average Injury Severity Score was 28 (16–50). Statistically significant improvement in pulse rate and blood pressure was noted following femoral fracture fixation with intramedullary nail. No cases of infection or symptomatic fat or pulmonary embolism were encountered. One patient required exchange nailing for non-union and one femur underwent later lengthening.

Conclusions: Retrograde Intramedullary femoral nail can be an effective alternative to external fixator as damage control device and is associated with immediate improvement in vital signs (pulse and blood pressure) intra operatively.

Background

The optimal type and timing of management of femoral shaft fractures in multiply injured patients and hemodynamic instability remains controversial with opinions ranging from early total care to delayed intervention with many other protocols in between [1–3]. A subgroup of patients (the at risk or borderline patients) were found to benefit from temporary external fixation (EF) and later conversion to intramedullary femoral nailing (IMN) as part of what is called damage control orthopaedics (DCO) [4]. However, EFs afford only partial fracture reduction and stability yet may be associated with pin site infection and knee stiffness. Conversion of EF to IMN is a major procedure with potential local and systemic complications [5,6].

We have been using retrograde intramedullary femoral nails (RIMFN) without proximal locking for “the at risk patients” following a positive experience in the index case (she had bilateral femur shaft and bilateral open tibial fractures) in which we could not use EF...
due to a mass causality incident.

We present a retrospective review of eleven consecutive multiply injured patients (14 femurs) with hemodynamic instability for whom femoral shaft fracture fixation was achieved using RIMFN as part of our DCO protocol between 20th of March 2013 and 7th of April 2020. We observed immediate improvement in BP and pulse rate (PR) following RIMFN insertion.

**Patients and methods**

An institutional review board approval was obtained for the study (MREC NO.1787). All patients who were deemed borderline with hemodynamic instability [7] (systolic BP ≤ 90 mmHg, PR ≥ 100 beats/minute despite fluid resuscitation, need for vasopressors, Table 1

| Inclusion & exclusion criteria. |
|--------------------------------|
| **Inclusion criteria** |
| - Polytrauma patients with established shock not responding to blood or fluid resuscitation. |
| - Exclusion of other external or internal causes for hemodynamic instability radiologically &/or by laparotomy |
| - Patients who underwent RIMFN at presentation immediately & were transferred directly from ER to OR following no response to resuscitation. |
| - Persistent hemodynamic instability despite control of intraabdominal bleeding. |
| - Age 16 to 60 years of both sexes |
| **Exclusion criteria** |
| - All patients who underwent surgery beyond 6 h |
| - Hemodynamically stable patients. |
| - Patients that responded to fluid and blood therapy |
| - Patients with other bleeding sources that responded to radiological or surgical control of those injuries |
| - Patients younger than 16 or older than 60 years |

Table 1

Inclusion & exclusion criteria.

**Patients and methods**

An institutional review board approval was obtained for the study (MREC NO.1787). All patients who were deemed borderline with hemodynamic instability [7] (systolic BP ≤ 90 mmHg, PR ≥ 100 beats/minute despite fluid resuscitation, need for vasopressors, Table 2

| Clinical summary of cases. |
|---------------------------|
| **No** | Age | Sex | Mechanism | MSK injuries | OTT | ISS | 2nd Op | VD | Inotropes | Remarks | Year treated |
| 1 | 34 | M | Fall of heavy machinery | FSF | 27 | 27 | PL | 1 | | | 2017 |
| 2 | 31 | M | MVC | Bil FSF | 52 | 16 | PL | 0 | | Spinal anaesthesia | 2016 |
| 3 | 27 | F | MVC | FSF | 32 | 18 | PL | Exch. IMN | 1 | | 2016 |
| 4 | 30 | M | MVC | Bil FSF + foot + hand injury Ipsil NoF + FSF | 59 | 26 | PL | 1 | 6 h | | 2016 |
| 5 | 24 | M | MVC | Ipsil NoF + FSF | 33 | 16 | PL | 1 | | | 2017 |
| 6 | 30 | F | Fall from height | FSF + PF + open HSF + FAF | 30 | 50 | PL | 13 | Stopped intraop after IMN | | 2017 |
| 7 | 31 | M | MVC | Left FSF + right HSF | 33 | 34 | PL | 1 | | | 2018 |
| 8 | 20 | F | MVC | Bil closed FSF + Bil open TSF | 55 | 29 | PL | lengthening | 14 | | 2013 |
| 9 | 30 | M | Fall from height | Left FSF + right HSF + left AF | 29 | 34 | PL | 5 | 6 h | Desaturated 2nd day. CT angio ruled out PE | 2016 |
| 10 | 36 | M | MVC | Right Ipsil. NoF + FSF + left CSF | 28 | 26 | Nil | 1 | | Desaturated 2nd day. CT angio ruled out PE | 2016 |
| 11 | 22 | M | MVC | FSF + PF + DHF + open TSF + Talus + MM + Calcaneum Fractures on left side + Right foot multiple MTB fractures | 35 | 29 | Tibia circular fixator + PL + Talus fixation | 1 | 6 h | | 2020 |

**MSK**: Musculoskeletal; **OTT**: Operation Theatre Time (Femoral shaft fracture fixation in minutes); **ISS Score**: Injury Severity Score; **VD**: Ventilator Days; **MVC**: Motor Vehicle collision; **MTB**: Metatarsal bone; **MM**: Medial Malleolus; **IUD**: Intra uterine death; **DIP**: Distal Interphalangeal joint; **NoF**: Neck of Femur; **FSF**: Femur Shaft Fracture; **HSF**: Humerus Shaft fracture; **DHF**: Distal Humerus fracture; **PF**: Pelvic Fracture; **FAP**: Forearm Fracture; **TSF**: Tibial Shaft Fracture; **WF**: Wrist Fracture; **AF**: Acetabular Fracture; **CSF**: Clavicle Shaft Fracture; **Ipsil**: Ipsilateral; **Bil**: Bilateral; **LVF**: Lumbar Vertebral Fracture; **PT**: Pneumothorax; **Preg**: Pregnant; **HPT**: Haemopneumothorax; **RF**: Rib Fractures; **HT**: Haemothorax; **LL**: Liver Laceration; **2nd Op**: Secondary Operation; **PL**: Proximal Locking; **LFU**: Lost to Follow Up; **CTCOA**: CT scan of chest on arrival.
Table 3
Intraoperative vital sign recordings.

| Case | Time interval in minutes |
|------|--------------------------|
|      | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 |
| 1    | SBP90 | SBP100 | SBP110 | SBP115 | SBP120 | - | - | - | - | - |
|      | DBP50 | DBP90 | DBP80 | DBP82 | DBP75 | - | - | - | - | - |
|      | P95 | P100 | P92 | P85 | P80 | - | - | - | - | - |
| 2    | SBP 90 | SBP 100 | SBP 110 | SBP 110 | SBP 100 | SBP 110 | SBP 110 | SBP 110 | - | - |
|      | DBP50 | DBP50 | DBP60 | DBP50 | DBP65 | DBP50 | DBP65 | DBP70 | DBP75 | DBP80 |
|      | P100 | P105 | P95 | P100 | P100 | P105 | P95 | P90 | P85 | P80 |
| 3    | SBP 60 | SBP 70 | SBP 70 | SBP 90 | SBP110 | SBP120 | SBP120 | - | - | - |
|      | DBP40 | DBP50 | DBP45 | DBP50 | DBP60 | DBP70 | DBP70 | DBP80 | DBP82 | DBP79 |
|      | P120 | P115 | P117 | P120 | P105 | P90 | P85 | P80 | P80 | - |
| 4    | SBP 70 | SBP 70 | SBP 60 | SBP90 | SBP100 | SBP115 | SBP120 | SBP115 | - | - |
|      | DBP 60 | DBP 45 | DBP60 | DBP70 | DBP80 | DBP80 | DBP80 | DBP80 | DBP60 | - |
|      | P 115 | P 120 | P117 | P100 | P100 | P90 | P85 | P80 | P80 | - |
| 5    | SBP97 | SBP100 | SBP90 | SBP95 | SBP95 | SBP100 | SBP110 | SBP112 | - | - |
|      | DBP65 | DBP70 | DBP50 | DBP60 | DBP63 | DBP60 | DBP55 | DBP60 | DBP60 | DBP60 |
|      | P102 | P100 | P99 | P95 | P90 | P84 | P80 | P75 | P80 | - |
| 6    | SBP95 | SBP100 | SBP102 | SBP110 | SBP115 | SBP117 | SBP110 | - | - | - |
|      | DBP60 | DBP60 | DBP65 | DBP60 | DBP70 | DBP75 | DBP60 | - | - | - |
|      | P100 | P93 | P97 | P90 | P90 | P95 | P95 | - | - | - |
| 7    | SBP82 | SBP85 | SBP90 | SBP95 | SBP100 | SBP95 | SBP100 | - | - | - |
|      | DBP65 | DBP50 | DBP60 | DBP50 | DBP55 | DBP60 | DBP60 | - | - | - |
|      | P110 | P102 | P115 | P100 | P95 | P87 | P80 | - | - | - |
| 8    | SBP90 | SBP80 | SBP90 | SBP95 | SBP90 | SBP80 | SBP80 | SBP90 | - | - |
|      | DBP20 | DBP40 | DBP50 | DBP45 | DBP55 | DBP60 | DBP45 | DBP60 | DBP55 | DBP60 |
|      | P135 | P115 | P120 | P100 | P110 | P115 | P102 | P117 | P99 | P95 |
| 9    | SBP77 | SBP80 | SBP80 | SBP80 | SBP80 | SBP80 | SBP80 | - | - | - |
|      | DBP50 | DBP45 | DBP50 | DBP50 | DBP55 | DBP55 | DBP55 | - | - | - |
|      | P133 | P108 | P112 | P105 | P90 | - | - | - | - | - |
| 10   | SBP100 | SBP100 | SBP90 | SBP95 | SBP100 | - | - | - | - | - |
|      | DBP50 | DBP60 | DBP55 | DBP52 | DBP60 | - | - | - | - | - |
|      | P103 | P90 | P92 | P85 | P80 | - | - | - | - | - |
| 11   | SBP67 | SBP100 | SBP70 | SBP70 | SBP75 | SBP100 | - | - | - | - |
|      | DBP35 | DBP40 | DBP40 | DBP35 | DBP60 | DBP60 | DBP60 | - | - | - |
|      | P140 | P145 | P140 | P135 | P130 | P130 | - | - | - | - |

SBP: systolic blood pressure; DBP: diastolic blood pressure; P: pulse.

elevated lactate levels at presentation were included. Inclusion and exclusion criteria are listed in Table 1. The following is a summary of the patients' clinical details: average age 28 years (20–36); 8 males; 8 caused by motor vehicle crashes and 3 due to fall from height; average injury severity score (ISS) 28 (16–50) (Table 2); average emergency room vital signs were PR 116 beats/minute (100–140), systolic BP 76 mmHg (55–90) and diastolic BP 43 mmHg (20–50). Table 3 details the intraoperative vital signs. The average temperature recorded on arrival was 36.8 °C (36–37.6) and initial mean and (range) laboratory parameters were as follows: Hb 13 (7–17), platelets 280 (132–386), WBC 17 (6–29), INR 1 (0.85–1.1), pH 7.2 (7.1–7.4), pCO2 41 (36–45), pO2 173 (83–341), HCO3 19 (12–25), base excess −6.5 (−16.9–0.7), and lactate 3.9 (1.7–6.4) (Tables 4 & 5). In terms of skeletal injuries, 2

Table 4
Blood investigations.

| Case | Hb | Platelet count | WBC | INR | Body temperature on arrival (°C) |
|------|----|----------------|-----|-----|-------------------------------|
|      | OA | PO | OA | PO | OA | PO | OA | PO |
| 1    | 15.1 | 9.5 | 386 | 190 | 14.9 | 18.4 | 0.96 | NA |
| 2    | 14.5 | 11.3 | 254 | 192 | 22.9 | 8.2 | 1.03 | NA |
| 3    | 7.4 | 8.1 | 132 | 133 | 5.7 | 6.5 | 0.85 | 0.94 |
| 4    | 15.3 | 11.8 | 251 | 220 | 25.2 | 18.6 | 1.12 | 1.07 |
| 5    | 14.2 | 9.9 | 364 | 281 | 9.1 | 7.2 | 1.02 | NA |
| 6    | 9.3 | 6.1 | 199 | 86 | 16.5 | 14.6 | 0.91 | 1.33 |
| 7    | 12.2 | 9.3 | 296 | 243 | 6.6 | 6.3 | 1.01 | NA |
| 8    | 8.3 | 3.2 | 292 | 118 | 16.2 | 5.6 | 1.06 | 1.44 |
| 9    | 17.4 | 11.5 | 372 | 152 | 29.0 | 15.3 | 1.11 | 1.10 |
| 10   | 14.1 | 10.4 | 238 | 170 | 10.5 | 5.1 | 0.99 | 1.17 |
| 11   | 10.0 | 7.3 | 286 | 41 | 28.9 | 10 | NA | 1 |

Hb: haemoglobin WBC: white blood cell count INR: international normalized ratio.
OA: on arrival PO: post-operative NA: not available.
patients had isolated femoral shaft fractures while 9 had multiple skeletal injuries, including open tibia, pelvis, acetabulum, spine, and 3 bilateral femoral shaft fractures. All were closed fractures with AO/OTA types: 7 32A, 3 32B, 3 32C, and 1 32C*K (Table 6).

All patients were initially evaluated by a multidisciplinary trauma team based on ATLS guidelines and were intubated (except 1) in the emergency room (ER), including FAST abdominal and pelvic scans. Total body CT scan was performed in patients who responded to initial fluid resuscitation using 2 l of crystalloids, blood and blood products. Unstable patients with femur shaft fractures were immediately transferred to the operating room (OR) for RIMFN. Intraabdominal bleeding management, if present, took precedence. Subsequently, RIMFN stabilization was performed in the same anaesthetic session. The appropriate diameter (nail 9-12 mm/medullary canal 11–15 mm) nail (Table 6) was, gently, inserted without guide wire and without any reaming and locked distally only. Proximal locking was deferred to a later date (Image 1a and b). Inotropes were started for four patients in ER (Table 2). They were discontinued for one patient intra operatively after RIMFN while three patients required inotrope support for six hours after surgery. Proximal locking was carried out 3 to 7 days later.

**Statistical analysis**

Immediate preoperative vital signs readings were compared to the postoperative (recovery room) readings using univariate repeated measure Annova (SPSS Version 26).
Results

The average operating time was 29 min (27–35) for unilateral and 55 min (52–59) for bilateral femur fractures. There was a statistically significant increase in the average systolic BP from 83 mmHg pre-op (SD = 13.3) to 106 mmHg (SD = 10.8) post-op (95% CI p = 0.002) (Fig. 1) and diastolic BP from 50 mmHg (SD = 13.7) pre-op to 67 mmHg (SD = 9.4) post-op (95% CI p = 0.006). There was a statistically significant drop in the average PR from 114 (SD = 16) pre-op to 87 (SD = 15.1) post-op (95% CI p = 0.000) (Fig. 2). ICU stay ranged from 0 to 14 days (mean = 3.5; mode = 1 day).

None of the patients died, developed symptomatic fat embolic syndrome (FES), pulmonary embolism (PE), adult respiratory distress syndrome (ARDS) or pneumonia. Five patients developed basal lung atelectasis and three had oxygen desaturation but CT angiogram ruled out PE & FES (Table 8).

Three patients returned to their home countries following discharge and were lost to follow up. One femur underwent exchange nailing for nonunion and another had to be lengthened. One knee had limited flexion due to severe soft tissue injury. There were no local infections.

Discussion

An ideal solution for femoral shaft fractures in the at risk or borderline patient remains to be found. Unfortunately, most of the literature compares EF to antegrade femoral nailing. Temporizing EF, especially for those with chest injury [4], is advocated because it is a relatively short procedure and avoids medullary canal reaming and embolization of its contents which are thought to predispose to inflammatory response and ARDS. However, this protocol has its own deficiencies and potential complications. Many studies have cast doubt on the relationship between femoral fracture nailing, inflammatory response and pulmonary complications [2,3,8]. Meanwhile, excellent results were reported using RIMFN in bilateral femur fractures and unstable patients [9,10]. Prolonged shock is likely to lead to poor outcome [7] and therefore its efficient and effective control is vitally important. We found RIMFN...

Table 7
Details of associated injuries.

| Case | Head & neck | Thorax | Abdomen | Pelvis & extremity | External/general | ISS |
|------|-------------|--------|---------|-------------------|-----------------|-----|
| 1    | –           | Pneumothorax (R) Chest + rib fractures AIS 3 | L4 burst fracture + multiple lumbar compression fractures AIS 3 | (L) femur shaft fracture AIS 3 | – | 27 |
| 2    | –           | –      | –       | Bilateral femoral shaft fractures AIS 4 | – | 16 |
| 3    | –           | Pneumothorax (L) Chest + rib fractures AIS 3 | Tear in mesentery + Gravid uterus with IUFD AIS 3 | Bilateral femoral shaft fracture + (L) iliac bone open fractur + (L)wrist vascular injury AIS 5 | (L)Neck of femur fracture with Ipsilateral shaft of femur fracture AIS 5 | 26 |
| 4    | –           | –      | –       | Bilateral femoral shaft fracture + (L) iliac bone open fractur + (L)wrist vascular injury AIS 5 | – | 16 |
| 5    | –           | –      | –       | – | – | – |
| 6    | –           | Hemopneumothorax + rib fractures AIS 3 | Vertebral fracture D5 with paraplegia AIS 4 | Pelvic fracture + (R) femur shaft fracture + right floating elbow AIS 5 | – | 50 |
| 7    | –           | (R)chest hemotorax + rib fractures AIS 3 | Free fluid in abdomen AIS 3 | (L) femur and (R) humerus shaft fracture AIS 4 | – | 34 |
| 8    | –           | –      | –       | Bilateral closed femur fracture + bilateral open tibial fractures AIS 5 | – | 29 |
| 9    | –           | (R)Pneumothorax (R) Lung contusion and rib fractures AIS 3 | – | (L) femur shaft + (R) humerus shaft + (R) distal radius fracture + (L) acetabulum fracture + (L) open supracondylar humerus fracture AIS 5 | Multiple laceration in back AIS 2 | 35 |
| 10   | –           | (L) rib fractures and lung contusion AIS 3 | – | (R) neck of femur fracture + ipsilateral shaft of femur AIS 4 | (R) sided forehead abrasion AIS 1 | 26 |
| 11   | –           | T 7 and T 9 wedge fractures AIS 2 | Liver and spleen grade I tear AIS 3 | (L) femur, (L) open tibia shaft + (L) Distal humerus + (L)MM ankle + (L) talus + (L) calcaneus fractures AIS 4 | – | 29 |

AIS: Abbreviated injury score; ISS: Injury severity score; R: Right; L: Left; IUFD: Intra uterine fetal death.
Image 1. X-rays of case 2.

a: X-rays of case 2 (bilateral femur shaft fractures) Anteroposterior view. Bilateral femoral shaft fractures in borderline patients present a unique scenario inadequately addressed by external fixators and conventional nailing protocols.

b: X-rays of case 2 (bilateral femur shaft fractures) Postoperative view. The total operating time for both femurs was 52 min. Proximal locking screws (absent in this post-op xray) were inserted 5 days later.
Figs. 1 & 2. Show the Estimated Marginal Means of the Systolic blood pressure and pulse respectively, comparing the values recorded on arrival in operating room and values after the patient was shifted to recovery ward. Statistically significant improvement was noted between the two values.

Figs. 1 & 2. (continued)
| Case | Immediate complication | Early complications | Late complication | Final result |
|------|------------------------|---------------------|------------------|-------------|
| 1    | –                      | Bilateral basal lung atelectasis | –                | Healed      |
| 2    | –                      | –                   | –                | Lost to follow up after proximal locking at day 5 |
| 3    | –                      | Bilateral basal lung atelectasis | Non union       | Healed after exchange nailing |
| 4    | –                      | Bilateral basal lung atelectasis | –                | Lost to follow up after proximal locking at day 7 |
| 5    | –                      | –                   | –                | Healed      |
| 6    | –                      | Bilateral basal lung atelectasis | –                | Lost to follow up after proximal locking at day 7 |
| 7    | –                      | –                   | Healed with shortening of length | Healed (required lengthening procedure) |
| 8    | –                      | –                   | Anterior knee pain | Healed      |
| 9    | Desaturated second post op day (investigation did not show any evidence of pulmonary or fat embolism) | Left lung atelectasis | –                | Healed      |
| 10   | –                      | –                   | –                | Healed      |
| 11   | –                      | –                   | Under follow up  | Under follow up |
without proximal locking to be efficient, effective, and safe. Efficiency is demonstrated in the short surgical time which is aided by simple supine position on standard radiolucent operating table and direct fracture reduction by the nail as a joystick. Efficacy is demonstrated by the immediate improvement in BP and PR following RIMFN insertion effected by the perfect fracture reduction, cessation of medullary bleeding and soft tissue tamponade effect (Fig. 3). Safety is demonstrated by the survival of all the patients with short ICU stay and no pulmonary or other organ dysfunction. It is important to note that the nail is cannulated, 3 mm smaller in diameter than the medullary canal, and is inserted gently without reaming other than for the entry point. This technique and protocol are significantly different from the conventional antegrade and retrograde nailing techniques. The primary aim here is DCO by immediate and effective hemodynamic stability through near perfect fracture reduction and relative mechanical stability. The retrospective nature of this study and the small number of patients are major limitations. However, the excellent results in this consecutive very difficult group of patients warrant further study of RIMFN without proximal locking as a DCO protocol through multicenter clinical trials and animal studies.

Declaration of competing interest

Authors declare no conflicts of interest, including financial, consultant, institutional and other relationships.

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