The author's cohort: a snapshot of the general situation

The following results were compiled from patients screened and treated from December 2017 to September 2018 by the author. The aim of the data presented below is to demonstrate the current nature of the wounds and demonstrate how time delay has manifest in the evolution of the surgical problems within the cohort. Each heading below defines clinical observations based on thorough clinical assessment of each patient presenting.

The cohort

From 10 December 2017 to 7 September 2018 a total of 90 patients with lower limb GSWs were screened by the author. The final cohort consists of 86 ballistic injuries to the limb. Three patients were excluded due to incomplete acute records and missing acute x-rays. Another patient was excluded as he presented with osteomyelitis (OM) from a GSW pre-dating the current crisis. The final 86 patients had full records that could be traced from their acute injury to their presentation at screening clinic as well as full documentation of their surgical management post-screening.

The mean age of the patients was 25 years (range 15-60 years of age). Five were minors (less than 17 years old). The majority were male (one female patient). Ninety-sever percent (83/86) patients had sustained a compound fracture: two of the upper limb, 81 where of the lower limb. Three cases had extensive lower limb soft tissue injuries without fracture.

Eighty-six percent (71/83) of the compound fractures had an external fixators in situ at screening (69 leg and two arms). Twelve compound fractures had no fixator: either external fixation was not necessary acutely or the fixator had already been removed prior to screening.

Following screening clinic, the cohort could be divided into those who still had open injuries and more wound care (56/86: 65%) and those who needed only monitoring, removal of their external fixators and rehabilitation (30/86: 35%).

Of the patients with ongoing open wounds, 54 were lower limb, two upper limb injuries. Ninety-five percent (53/56) had sustained acute, compound fractures. 26 had open wounds with persistent bone exposure. Thirty had open wounds but no remaining bone exposure.

Eight patients presented with unhealed donor sites from split skin graft (SSG) harvest. For two patients, this was the only remaining open injury. For six other patients, the unhealed SSG donor sites were accompanied by unhealed distal GSW injuries.

Eight patients (9%) had bilateral injuries: two had received below knee amputations acutely. Excluding the two amputees, bilaterally injured patients presented with one severely injured leg and a minor injury to the contralateral side caused by the same bullet. All patients had one good leg to stand on.

Timing and side of the injury

There were more casualties on three specific dates (Table 1); 30 March 2018 and 14 May 2018 correspond to the dates where more than 500 patients were estimated to have attended the local emergency departments in one day. Fifty-six percent (48/86) of the cohort received their GSW on one of three dates of protest.

The right leg seems to be the commonest side of injury overall when the dates are combined (Table 2). Numbers in the cohort are small relative to the total numbers injured, but there seems to be a targeted side of injury on the days of heaviest conflict.

Both GSWs to the arm where on the left side.

Table 1: Recorded date of original gunshot wound for patients presenting at screening clinic.

Date acute GSW	Patient count	Percentage of cohort
30/03/2018	16	19%
13/04/2018	7	8%
14/05/2018	25	29%
Other dates	38	44%

Table 2: Record of side and date of Gunshot wound to limb for the three commonest dates of injury.

Date of GSW	Total number casualties that day	Right	left
30/03/18	16	11 (69%)	5 (31%)
14/05/18	25	16 (64%)	9 (36%)
13/04/18	7	2 (29%)	5 (71%)
Combined figures for above dates	48	29 (60%)	19 (40%)

Components of the wound documented at screening

The records below document the injuries as they presented at orthoplastic screening clinic. No patient was assessed acutely on the day of injury: these wounds are all second wave presentations to an elective outpatient screening programme. Components of injury are divided into bone elements and soft tissue elements.

Bone injury

Ninety-four percent (81/86) of patients had compound fractures of the leg. Two had compound fractures of the upper limb. Three patients had severe soft tissue injuries without fractures. Two were unilateral amputees with associate compound fractures on the remaining leg.

The lower limb injuries were classified according to the Gustilo Anderson classification (Table 3) [1,2]. The commonest fracture was a Gustilo IIIb. Combined, Gustilo IIIb and IIIc constituted 65% of the fractures.

Table 4 summaries the bones involved in the 83 fractures. Table 5 summarises the level of the injury within the long bone. Comminution extended over more than a third of the bone length in 28% of the cases. Ninety percent of the fractures had marked comminution (Table 6). Thirty percent (24/81) of patients demonstrated a bone gap i.e. significant segmental bone loss.

Most fractures were extra-articular (67/83, 81%). Nineteen percent (16/83) of the fractures were intra-articular (five ankles, eight knees, two sub-talar joints and one tarso-metatarsal injury).

Table 3: Gustilo Anderson classification of compound lower limb fracture within the cohort.

Gustilo Anderson classification	Patient number (81 cases with compound fractures)	Percentage (81 limb fracture cases)
I	3	4%
II	11	14%
IIIa	14	17%
IIIb	36	44%
IIIc	17	21%

Table 4: Bones involved in compound fractures of lower and upper limbs within the cohort screened at clinic.

Bone involved	Number of patients	Percentage of fractures
Tibia and fibula	49	59%
Femur	17	21%
Tibia alone	7	8%
Fibula alone	3	4%
Sub-talar joint	3	4%
Metatarsals	1	1%
Calcanium	1	1%
Humerus	2	2%

Table 5: The level of injury within the long bone of the limb recorded for patients seen at screening clinic.

Level of the fracture in long bone shaft	Number of patients out of 83 fracture	Percentage
Proximal 1/3	19	23%
Middle 1/3	19	23%
Distal 1/3	22	27%
Junction of proximal and middle 1/3	16	19%
Junction of middle and distal 1/3	7	8%

Table 6: Degree of comminution and bone gap observed following GSW injury within cohort screened.

X-ray review (81 patients)	No. patients	Percentage
Bone comminution		
Minimal	8	10%
0-5cm	34	42%
5-10cm	27	33%
10-15cm	12	15%
Bone gap		
Minimal	57	70%
0-5cm gap	18	22%
5-10cm gap	6	8%

Soft tissue injury

Soft tissue injury occurred in two phases: 1) Acute soft tissue loss at the GSW injury; 2) Subsequent soft tissue damage from wound neglect or from complications of surgical interventions. A clear history was recorded of interventions and outcomes from the day of acute injury up to the day of screening.

Condition of wounds at the time of screening were as follows: 65% (56/86) of the cohort presented with open wounds. Ninety-five percent (95%) of the open wounds were associated with compound fractures at acute injury. Five percent (3/56) had no underlying fracture site.

Of the open wounds associated acutely with compound fractures 46% (26/56) still had exposed bone or exposed fracture evident at screening. Forty-eight percent (27/56) of the original compound fractures had no remaining exposed bone. Closure had been completed either by surgical intervention or, in the absence of surgery, by soft tissue healing by secondary intention.

Vascular injury

Acute vascular injury was recorded in 24 lower limb injuries (24/83: 29%). The acute management of the vascular injuries were recorded retrospectively from notes and patient history (Table 7). The posterior tibial artery was the most commonly damaged vessel. Forty-two percent of the vessels were ligated, 17% repaired with a vein graft, 38% repaired by direct anastomosis.

Acute fasciotomies were performed in 18 cases. Fourteen fasciotomies were performed in conjunction with vascular repairs. All cases receiving a vascular repair with vein graft had had acute fasciotomies. At screening clinic, eight patients had closed fasciotomy sites. Eight still had both medial and lateral fasciotomy wounds open. Two had lateral wounds closed but medial sites still open.

Four fasciotomies were performed in cases with no recorded vascular injury. These were for episodes of acute compartment syndrome or in patients at high risk of this.

Four patients presented with established damage from compartment syndrome: the clinical presentation of these are summarised in Table 8.

Nerve injury

These results are based on clinical examination only at screening clinic. The acute intraoperative findings were not available nor nerve conductions studies. Eighty-two of the 86 cohort had their nerve function recorded at screening.

Nerve injury was confirmed in 34/82 (41%) cases. Tibial and peroneal nerves were the commonest nerves injured, either alone or in combination (Table 9). This correlates with the zone of injury. Seventy-one percent of the compound injuries involved tibia, fibula or both.

Twenty-one patients (62% of nerve injuries) had complete nerve palsies. Eight patients (23%) reported altered sensation as the only deficit. Three patients (9%) reported full loss of sensation but with intact motor function. One patient (3%) demonstrated motor loss but some return of sensation. One patient (3%) demonstrated mixed patchy loss of sensory and motor function.

The complications of neuropathic feet were evident: four patients had decubitus ulcers on heel pads. One patient had sustained accidentally a full thickness contact burn on the plantar surface over the metatarsal heads.

Combined injury / degree trauma

The greater the violence of the original trauma, the more likely the injury sustained combined fracture with neurovascular damage.

Table 7: The acute surgical management of the vascular injuries by local teams.

Vessel involved	Number patients injured	Direct repair / anastomosis of divided vessel	Vein graft	Vessel ligated	Unknown Management vessel
Femoral artery	3	3	0	0	0
Popliteal artery	4	1	3	0	0
Posterior tibial artery	6	1	1	3	1
Peroneal artery	1	1	0	0	0
Anterior tibial artery	2	0	0	2	0
Unknown vessel	8	3	0	5	0

Table 8: Clinical presentation of four cases with the sequelae compartment syndrome noted at screening.

Vascular injury and repair	Acute fasciotomy	Gustilo Anderson classification	Consequence of compartment syndrome
Pt 1: no vascular injury recorded	no	IIIb	Fibrosis deep posterior compartment
Pt 2: Popliteal artery division: acute vein graft	Medial and lateral	IIIc	Loss of posterior and lateral compartments
Pt 3: Unknown vessel divided: direct anastomosis	Medial and lateral	No fracture	Loss of both posterior compartments.
Pt 4: Unknown vessel: ligated	Medial and lateral	IIIc	Partial muscle fibrosis all compartments

Table 9: Anatomical distribution of nerve injury in the cohort secondary to GSW injury.

Nerve injury	Patient numbers	Percentage of cohort
Peroneal nerve	11	13%
Tibial nerve	7	8%
Peroneal and tibial nerves combined	11	13%
Sciatic Nerve	4	5%
Medial plantar nerve	1	1%
No record in notes	4	5%
No nerve injury	48	56%

The patients presenting to screening with ongoing open wounds are likely to have sustained a higher degree of acute injury. Forty-five percent (25/56) had nerve injuries. Thirty-two percent (18/56) had vascular injuries. Forty-one percent (23/56) had a nerve injury combined with a fracture and 13/56 (23%) had a neurovascular injury combined with a fracture.

Ninety-five percent (20/21) of the complete nerve palsies were related to fractures (predominantly Gustilo III fractures: IIIa: three cases, IIIb: eight cases, IIIc: eight cases). Only one complete nerve injury was associated with a Gustilo I: a femoral fracture with sciatic nerve involvement.

One complete nerve palsy was related to a posterior compartment syndrome in the absence of a fracture.

Secondary surgical interventions: procedures undertaken between the acute GSW injury and before screening clinic

By the date of screening, 61/86 (71%) patients in the cohort had had some secondary surgical intervention after their acute care. This was either by local teams or non-governmental organisations (NGOs).

a) Secondary bone interventions completed prior to screening

Application and adjustment of external fixators

Eventy-one of the 83 patients (86%) with compound fractures presented at screening clinic with an external fixator in place. Acute primary debridement, with immediate application of an external fixator, was performed on 50/71 cases (70%).

A further 21/70 cases (30%) needed fixators acutely but received these within three days of injury (mean 2.9 days: range 1-12 days). The 12-day delay related to a femoral vascular repair with complications.

Local teams subsequently adjusted 3/71 external fixators (mean 16 days from GSW; range 5-40 days). A further four fixators where exchanged to different types fixators (mean 21 days from GSW; range 10-42 days).

Internal fixation

Only two patients had internal fixation. One patient had compression screws for a complex, intra-articular, bi-condylar femoral fracture. The fracture was also supported by an external fixator. One patient had an elbow fracture with a humeral plate.

K-wire fixation / removal

One patient had acute reduction and k-wire fixation of a Lisfranc tarso-metatarsal fracture dislocation. This facture was complicated by infection and the wires removed 14 days post surgery.

Iatrogenic injury linked to bone interventions

For three patients, fixator pin placement was within fracture site. One patient had a broken drill bit in situ.

b) Secondary soft tissue interventions completed prior to screening

Table 10 summarises interventions completed by local teams and NGOs on patients prior to screening. These cover further debridments, grafts and local flaps.

Table 11 documents the orthopaedic and soft tissue complications from post-acute surgery prior to screening.

Table 10: Secondary soft tissue interventions completed after the acute injury and prior to patient review at screening clinic.

Intervention pre-screening and patient numbers	Indications for previous intervention	Outcome and observations
Skin grafts – 17 patients	• To close fasciotomy wounds. • To close soft tissue areas around the GSW.	• The mean time from the original GSW to application of the graft was 20 days. • Six grafts failed. • Eight patients had iatrogenic injury to the SSG donor site from skin graft harvest.
Flaps: Local flaps for vascular tissue cover – 12 patients Eight by local teams, four by visiting NGOs. All had additional SSG to close flap donor sites and to cover any remaining graftable areas around the GSW not covered by the flap.	• To cover exposed fracture and bone.	• Seven flaps failed to cover compound fracture (three from local teams, four from NGOs). • Two patients were amongst the eight with iatrogenic injury to donor sites from skin graft harvest.
Debridements: 83 (97% of cohort) received an acute debridement on the day of injury. 88% of the cohort received further debridements.	• Further debridement of remaining necrotic tissue. • Further debridement in effort to keep wound clean in the absence of soft tissue closure.	Of those needing further debridement: • 30% had 1. • 40% had 2-4. • 9% had 5-9. • 12% had more than 15. (Range secondary debridements: 1-22 per patient).

Table 11: Summary of the complications and iatrogenic injuries recorded at screening in patients with GSW injuries to the lower limb.

Complications associated with interim surgery	Number patients
Pin tract infections	4
Neuropathic pressure sore	4
Wound infection	1
Haematoma	1
osteomyelitis	1
Loss flap	7
Loss SSG (x2 with flap, x4 SSG alone)	6
Infected k-wires	1
Septic arthritis	1
Iatrogenic injury	
Unhealed SSG donor site	8
Pin in # site	3
Drill bit in bone	1
Inappropriate nerve graft	1

Audit of antibiotic use

Ninety-seven percent (83/86) of patients gave a history of taking antibiotics at some point between GSW and before attending screening. At the time of screening 50 of the 83 patients with fractures were still taking antibiotics (60%). When asked how long they had been on antibiotic therapy, 24% did not know, 4% had been on for less than a week but 60% had taken antibiotics for 2-12 weeks (mean eight weeks). Nine different antibiotic types were named by the patients: cefuroxime was the most common preparation used (taken by 39% of the patients).

At screening, only eight patients had clear clinical signs of infection justifying targeted antibiotic use following swab results, bone culture and bacterial sensitivities. Most patients had contamination requiring further surgical debridement and washout only, not antibiotic therapy.

Second wave orthoplastic management proposed following screening

Combined orthoplastic assessment of the patients at screening was followed by the formulation of a management plan based on orthoplastic principles.

Orthopaedic plan

Table 12 summarises the orthopaedic plan. Although each fracture may have had more than one issue to treat, the table records the main management decision. Forty percent of the fractures had received good acute care and are likely to go to bone union following a programme of progressive weight bearing and physiotherapy. Thirteen percent needed minor adjustment of their existing external fixators. Seventeen percent needed attention due to infection or the presence of remaining necrotic bone (under-debridement). Thirty percent had reached a point where the decision had to be made whether the limb was salvageable, and would future secondary reconstructive surgery be appropriate.

Plastic surgery plan

At the time of screening 50% (43/86) patients needed no further plastic surgery intervention (Table 13).

Of the 56 patients with open wounds 15 (27%) would close with conservative dressing care alone. Three (5%) wounds could be closed directly without the need for specialist

Table 12: Summary of orthopaedic management plans based on patient limb condition at the time of screening.

Orthopaedic plan: main management plan for 83 fractures	Number of patients
Plan for progressive weight-bearing and removal of external fixator within six weeks: fracture uniting and alignment satisfactory	28
Refer to PT rehabilitation: joint peripheral to the fracture needs mobilisation or patient needing rehabilitation after satisfactory management of fracture.	5
Adjust frame without changing alignment (add bar or adjust / add pins).	2
Realign: correct angular or rotational deformity by frame adjustment alone.	7
Remove pin as in # site: iatrogenic injury.	2
Urgent washout: within 24 hours from review. Either septic arthritis or infected pin site.	4
Debride more bone: necrotic bone still in wound.	10
Shorten: Excise segment of non-viable bone and shorted to get union.	6
Masquelet: Excise bone segment or freshen bone ends to viable bone then apply gentamicin cement to bone gap.	7
Exchange external fixator to a circular frame: Taylor Spatial frames available.	7
Joint fusion.	1
Bone graft defect.	3
Established osteomyelitis: Patient clearly has bone infection: Modify to reconstructive program or amputation.	1

Key
- Black: good to go.
- Red: minor adjustment of external fixator.
- Blue: infection or necrotic bone needs addressing.
- Green: future, more complex surgery required versus simple salvage: will need further surgery / limb reconstruction programme.

Table 13: Plastic management plan following patient review with orthopaedic colleague at screening clinic

Plastics management plan for 86 patients in cohort at screening	Patient numbers
No further plastic intervention required at this moment	
No further debridement or soft tissue cover.	26
Regular dressings and follow up: wound open but will heal without further intervention.	15
Monitor nerve recovery: nerve repairs already performed locally.	2
Plastic intervention needed	
Debridement and direct closure by local team.	3
Require further debridement +/- graft +/- direct closure.	5
Flap: debride, bone excision and stabilisation, flap and SSG.	26
SSG alone to open wound: no tendon or bone exposure.	7
Amputation stump revisions: to allow satisfactory fit of a prosthesis.	2

Table 14: Summary of flap cover applied in the treatment of compound fractures of the lower limb following GSW: 20 flaps in 19 patients .

Flap type • Perforator + (P+) • Adhoc (AH) • Keystone IV (KS) • Reverse sural (RSA) • Medial Gastroc (MG)	**Pedicle / perforator source** • Tibial artery (PTA) • Peroneal artery (PA) • Peroneal and Sural Artery (PA+SA) • Anterior tibial artery (ATA) • Femoral perforator (FA) • Gastrocnemius perforator (GP) • Medial sural artery (MSA)	**Number of perforators supplying flap**	**Base** Proximally based (PB) Distally based (DB)	Delay applied	Masquelet applied	Complications
Flap 1: P+	PTA	1	DB		Y	
Flap 2: AH	FA	1	PB			
Flap 3: P+	PTA	1	PB			
Flap 4: P+/KS	PTA	2	DB			
Flap 5: AH	GP	1	PB			
Flap 6: P+	PTA	2	DB			Tip necrosis flap: fracture still covered
Flap 7: P+	PTA	3	BD			
Flap 8: AH	PA	1			Y	
Flap 9: P+/KS	PTA	3	DB			
Flap 10: P+	PA + SA		DB			
Flap 11: MG	MSA				Y	
Flap 12: MG	MSA					
Flap 13: P+	PTA	2	DB	Y	Y	
Flap 14: P+/KS	MSA + GP	2	PB			

plastic surgery. One compound injury needed orthoplastic care but was already scheduled for surgery with another NGO.

Thirty-seven (43% of the 86 patient cohort) were offered surgery by the author. All cases were in effect revision surgery: chronic open wounds in previously debrided legs.

Thirty-two (37%) of the 37 patients underwent surgery: 19 patients required flap cover, 12 patients needed further debridement and either SSG or direct closure. One upper limb fracture required only debridement and removal of the internal fixation plate, after which an orthopaedic colleague closed the wound directly.

Five of the 37 patients scheduled for surgery did not complete their planned management. Four patients wished to try and seek help outside the country. All four young men risked travel with contaminated, compound injuries. One patient was cancelled on the planned day of surgery as no orthopaedic surgeon or cement was available to do the Maquelet type intervention required.

a) Flap cover required

The type of flap and the outcome of each is summarised in Table 14.

Twenty flaps were undertaken in 19 patients (22% cohort, 34% of patients with open wounds). All had exposed bone at the time of surgery. Their fractures included: 12 Gustilo IIIb fractures, six Gustilo IIIc, one Gustilo II fracture.

Amputation was recommended as the best care for three patients at the time of screening. This conclusion was based on the very poor functional outcome they could expect from limb salvage and the high risks of future osteomyelitis. All three cases refused amputation accepting the likely poor outcome of salvage surgery and the immediate and long-term risks of infection.

Seventy-nine percent (15/19) of patients received immediate surgery post screening. Twenty-one percent (4/19) were accommodated on a subsequent mission, either because of lack of theatre time per mission or because the patients went to another NGO before returning to the author later.

For patients screened and treated on the same mission, the average time between the original GSW injury and wound closure was 34 days (range 5-72 days). The average time between the author screening the patient and closure was seven days (range 0-16 days).

For patients deferred to a later mission, the average time between the original GSW and wound closure was 82 days (range 78-117 days). The average time between the author first screening of these patients and surgical closure was 39 days (range 23-61 days).

Four flaps were raised with a bipedicled delay (range three to six days before division and inset) ensuring maximal flap length to address lower third leg and foot defects. Seven flaps cases were in conjunction with Masquelet type interventions [3,4]. Free tissue transfer is not an option in this context due to lack of availability of postoperative inpatient care, monitoring, availability of theatre time, and general appropriateness of violating distant donor sites for such badly damaged legs. In all cases, with careful planning, a perforator flap option was available.

The average number of theatre episodes for full debridement and flap closure was two operations per patient (range one to four episodes depending on debridements necessary +/- flap delay before complete closure).

Complications were limited to flap tip necrosis of 1cm in one flap. This was debrided without consequence as the remaining flap amply covered the fracture site.

b) Soft tissue defects without exposed bone

Twelve patients (14% of the cohort, 21% of open wounds at screening) required soft tissue cover. This included 11 lower limbs and one arm.

Three cases had extensive soft tissue trauma but no fracture, no exposed bone or exposed tendons.

Nine of the patients, who no longer had exposed bone, had sustained compound fractures acutely: eight legs and one arm. The lower limb fractures included four Gustillo IIIb, three IIIc and one IIIa. Previously exposed bone was now covered by tissues closed in by secondary intention because of time lapse before surgical attention.

Ninety-two percent (11/12) of patients were treated in the same mission following screening. The average time between the acute GSW and closure was 60 days (range 11-137). The author's average time from screening to closure was 10 days (range 0-15). Each patient averaged two debridements before definitive closure was possible (range 1-4). One patient was lost to follow-up after screening but presented again at a later mission: this wound was closed 64 days after the GSW and 35 days after the original screening.

These 12 soft tissue defects without exposed bone were addressed as follows. Three patients required simple debridement of their GSWs. Nine patients needed debridement and SSG of the GSWs. One patient required over-grafting of an unhealed SSG donor site as well as the distal GSW. One patient had debridement and grafting to a lateral fasciotomy site combined with debridement and direct closure of a medial fasciotomy site.

All soft tissue injuries were closed without complication at follow-up.

References

1. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am* 1976;**58**:453-8.
2. Gustilo RB, Mendoza RM, Williams DN. Problems in management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma* 1984;**24**:742-6.
3. Masquelet AC, Begue T. The concept of induced membrane for reconstruction of long bone defects. *Orthop Clin North Am* 2010;**41**:27-37.
4. K arger C, Kishi T, Schneider L, et al. Treatment of posttraumatic bone defects by the induced membrane technique. *Orthopaedics & Traumatology: Surgery & Research* 2012;**98**:97-102.