Injury, Int. J. Care Injured 50 (2019) 1376–1381

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

A comparison between the Major Trauma Centre management of complex open lower limb fractures in children and the elderly

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ARTICLE INFO

Article history:
Accepted 2 May 2019

Keywords:
Open fracture
Lower limb
Orthoplastics
Paediatric, elderly

ABSTRACT

Introduction: Open lower limb fractures can be devastating with outcomes determined by tissue damage and adherence to strictly defined care pathways. Managing such injuries in paediatric and elderly populations presents logistical and technical challenges to achieve best outcomes. Orthoplastic principles were developed mainly in the young adult population whereas requirements for paediatric and elderly patients need further understanding.

Methods: A retrospective analysis was performed on two groups of patients at the extremes of age, with type IIIb (severe) open lower limb fractures, presenting to a Major Trauma Centre (MTC) with orthoplastic services over a six-year period - the first group being under 16 years; the second group being over 65. The timelines of combined surgery to both fix the fracture and flap the soft-tissue defect were strictly observed. Each group were followed-up for a minimum of nine months. Data were analysed according to patient demographics, mechanism of trauma, time to wound excision, time to definitive surgery, fixation technique, soft-tissue reconstruction type, deep infection rate, flap survival, bony union, secondary amputation and functional outcome (Enneking score).

Results: 33 paediatric patients and 99 elderly patients were identified.

Paediatric: The median age was 12 years. All the children were ASA Grade I. Open tibial fractures were most common (76%) followed by ankle fracture dislocation (12%). The majority were high-energy injuries and were commonly managed with external fixators (or frames) and free flap coverage. Median hospital stay was 12 days, and time to union 114 days, with median Enneking scores of 85%. There was one flap failure and no deep infections.

Elderly: The median age was 76 years. ASA grades varied and reflected multiple comorbidities. High-energy injuries required free flaps, while more common, low-energy fragility fractures were covered with loco-regional flaps. Internal fixation with intramedullary nails was most commonly used. Median hospital stay was 13 days, and time to union was 150 days, with median Enneking scores of 70%. There was one flap failure, one deep infection, and one delayed amputation.

Discussion: These results reflect both similarities and important differences in managing open fractures in the extremes of age. The specific challenges of each group of patients are discussed, including surgical aspects, but also the importance of orthoplastics infrastructure within the MTC and input from allied professionals to facilitate patient pathways.

Introduction

Presentation of extremity trauma is protean and its ultimate effect on the form and function of the injured limb depends on many variables. Open fractures of the long bones of the lower limb represent a severe group of extremity trauma and can be limb threatening. In the United Kingdom standards of care have been introduced to improve outcomes [1]. These outcomes are affected by many variables, but what is unknown is if age has any long term bearing on functional outcomes. It is intuitive to think that energy transfer during the traumatic event leads to differing tissue damage depending on patient age. Frailty has been quantified and is known to signify vulnerability [2]. Thus, low energy events can result in devastating limb injuries in the elderly. Poor tissue quality is important, but open fractures must be respected as severe injuries regardless of how they were sustained. This implies that vascularized soft-tissue cover is mandated when the fractures are graded as Gustilo-Anderson grade IIIB and above. Free tissue

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https://doi.org/10.1016/j.injury.2019.05.001
0020-1383/

transfer in lower extremity trauma is now commonplace, and is recommended by some over local flaps [3–5]. It has been stated that advanced age should not be a contra-indication to free flap surgery [6,7]. However, whilst desirable, free tissue many not be reliable in the elderly when pre-injury conditions are taken into account [8]. This has made the decision-making processes even more difficult when faced with a low energy IIIB fracture in elderly patients who are medically unfit for prolonged surgery.

Severe open lower limb fractures in children under 16 are uncommon and those in under 10's even more so [9]. In 1996 Blaiser and Barnes reported that one had to be less aggressive in managing open tibial fractures in children under 12 [10]. There have been a number of large cohort studies that report on experience of specialist centres [11,12]. In a meta-analysis of eligible studies Gougoulias et al [9] found that grade III injuries were only present in 9.8% of cases and only 19.2% of cases required flap coverage. Interestingly the latter group found that grade III injury appeared to be associated with a poorer outcome. What is unclear in many studies is the accurate grading of the grade III injuries into grades a–c [13–15], since it is established that both management decisions and outcomes are dictated if the fracture is grade III A, B or C [16–20].

Most patients who sustain severe limb trauma are young adults. However, the elderly and paediatric populations are not immune from similar complex patterns of injury. This paper presents a large cohort of severe (IIIB) open lower limb fractures in these two distinct age groups who have been managed in a care setting, which offers complex definitive reconstruction of both the fractures, and the soft-tissue defects. We undertook a retrospective analysis of our cases collected over a 6-year period. The City of Bristol, UK, has two separate Major Trauma Centres (MTCs) one for adults and one for children, with the same group of 3 plastic surgeons covering both MTCs. This allowed a unique insight into the outcomes of these two separate populations of patients. We describe our experience and provide a safe algorithm for decision-making.

Methods

A retrospective analysis of data collected from our MS Excel database was performed over the period of 2011–2017. Our inclusion criteria for paediatric group were as follows: Age less than 16 years at the time of injury; severe open IIIB lower limb fracture [21] with a minimum of 9 months follow up. Our inclusion criteria for elderly group were as follows: Age 65 years or above; with a severe open IIIB lower limb fracture; and a minimum of 9 months follow up. All patients were managed postoperatively according to our lower limb flap protocol [22] and were followed up in a combined orthoplastic clinic for minimum of 9 months postoperatively.

Data were analysed according to patient demographics, mechanism of trauma, time to wound excision, time to definitive surgery, type of soft-tissue reconstruction, rate of deep infection (as defined by the Centre for Disease Control & Prevention criteria) [21,23,24], flap survival, bony union (assessed on plain x-rays or CT scans if required), secondary amputation and functional outcome measured using the Enneking score [25].

Results

Over the six-year study period (2011–2017), 33 paediatric patients and 99 elderly patients were managed in the North Bristol NHS trust between two major trauma centres; Southmead Hospital and Bristol Children Hospital.

All patients in both groups were managed according to BAPRAS / BOA Standards of care for open lower limb fractures [26].

Paediatric group

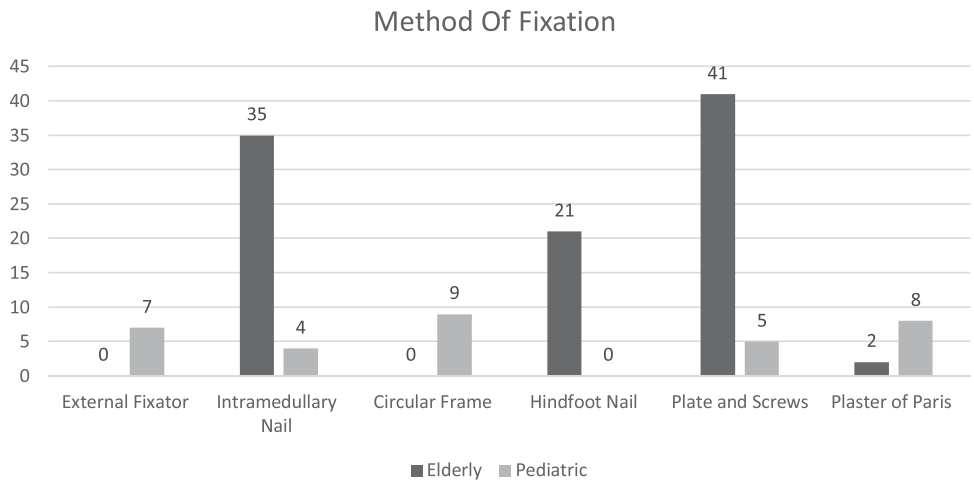
Thirty-three patients (21 male and 12 female) were managed for open IIIB lower limb fractures, 32 patients were high-energy injuries (all but one were motor vehicle collisions). The median age at time of injury was 12 years. All the children were American Society of Anaesthesiologist Physical (ASA) Grade I. Severe open tibial fractures were the most frequent lower limb injury presented among the paediatric age group (76% of patients) followed by ankle fracture dislocation (12% of patients) (as shown in graph x).

All patients were taken to theatre with a senior orthopaedic and plastic surgeon for first stage wound excision (debridement) and temporary stabilisation within one day from the time of injury.

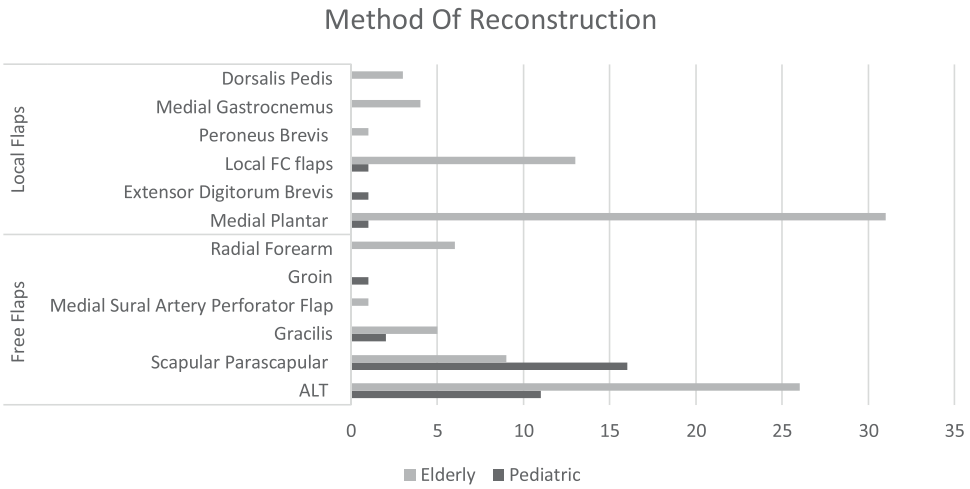
Patients had their definitive reconstruction in a combined orthoplastic second stage (fix and flap) at a median of two days from initial injury.

The method of definitive fixation and the flaps used for soft tissue reconstruction are presented in Graphs 1 and 2.

Patients had a median length of stay of 12 days. The Median time of bony union was 144 days from injury. Thirty-two patients had 100% flap survival rate (there were no partial failures). One patient had a total flap failure on day 4 post-operatively, which was managed with another free flap. There were no deep infections, and the median Enneking score was 85%.



Graph 1. Comparing the methods of fixations between Paediatric and elderly population.



Graph 2. Comparing the method of reconstruction between paediatric and elderly population.

Elderly group

99 patients (72 female and 27 male) were managed for open IIIB lower limb fractures. 69 patients sustained low energy fragility fractures due to mechanical falls, while the remaining 30 patients were high-energy injuries (mostly road traffic accidents). The median age at the time of presentation was 76 years.

(Table 1) shows the associated comorbidities and the ASA score of patients.

Tibial Fracture was the most commonly encountered injury (52%) followed by open fracture dislocation of the ankle (48%) (Table 1)

The median time from injury to initial wound excision was 1 day; and the median time from injury to definitive fixation and reconstruction was 2 days.

Pedicled flaps were used in 50 patients, while free flaps were used in 49 patients.

Graph 2 summarises the type of soft tissue reconstruction used in the elderly group.

The median length of stay in hospital was 13 days. 13 patients required admission to ICU for associated comorbidities and/or associated injures. 92 patients survived until 6 months follow up, 7 patients died before the follow up time due to causes other than the injury (Table 2).

Table 1
Showing the Frequency of Injuries, associated comorbidities and ASA grade of patients.

		Pediatric	Elderly
Site of Trauma	Foot	3	0
	Ankle	4	48
	Tibia	25	51
	Femur	1	0
Comorbidities	Diabetes	0	8
	Renal Disease	0	13
	Peripheral Vascular Disease	0	21
	Steroids	0	5
	Anticoagulants	0	24
	Cardiac	0	34
	Respirarory	0	21
	Smoking	0	9
ASA	I	33	7
	II	0	49
	III	0	33
	IV	0	4
	Non Recorded	0	6

Table 2
Comparison of paediatric versus elderly open fracture management.

	Paediatric (Median and range)	Elderly (Median and range)
Age (Years)	12 (5–16)	76 (65–95)
Time to wound excision (Days)	1(0–5)	1 (1–2)
Time to definitive fix & flap (Days)	2 (1–14)	2 (0–5)
Hospital Stay (Days)	12 (5–16)	13 (7–51)
Flap Failure	3%	1%
Time to bone healing (Days)	144 (81–588)	150 (41–459)
Enneking Score %	85 (65–92)	70 (25–92.5)
Amputation	0%	1%
Deep Infection	0%	1 %

The median time to bony union was 150 days. Free flap reconstruction failed in 1 patient and they underwent subsequent amputation. 1 patient requested amputation because she was not willing to undergo further reconstructive procedures. 1 patient developed infected non-union and was managed with bone transport. The median Enneking score was 70%.

Discussion

The proportion of the UK population who are elderly is growing which reflects a global trend. Within the next 15 years it is estimated that nearly a quarter of the UK population will be over 65 years of age [27]. Similarly, octogenarians will double in the United States of America by 2020 from the start of the new millennium [28]. Whilst longevity may be seen as an indicator of a successful healthcare provision, it can counter-burden resource allocation. Furthermore, increasing age will lead to a less resilient population with additional comorbidities that frequently culminate in frailty and cognitive impairment, that make people increasingly injury prone. Often the injuries are sustained from low energy impacts, but due to tissue fragility the injury can be devastating, with open fractures and damaged joints. Falls and fractures in the elderly are common, accounting for over 4 million hospital bed days each year in England alone [29]. The incidence of domestic trauma is on the rise from just 5% in 1990 to 40% in 2013 and low energy falls more often results in major trauma in the elderly than road traffic accidents [30]. While none of our elderly patients died during their admission, 7 patients did not survive to full follow-up, and died from causes not directly related to the injury.

Severe limb injuries in children are uncommon. These injuries are typically sustained during road traffic accidents (either as

pedestrians or passengers). Tibial fractures however only account for 5% of all the fractures in children under 16 [9]. The injury pattern is multiform depending on the circumstances for example a pedestrian child or one on a moped. This variation is such that in children, lower limb injuries lack robust scientific research to support any particular form of management over another [9,31]. Buckley et al treated 42 open tibial fractures found age irrelevant when reporting their outcomes [32]. Other studies, however, have suggested that children under the age of 12 require less aggressive surgery to achieve union with fewer complications [3,12,32–34] with the surgical intent being to save the child from the risks inherent in fracture fixation and of flap surgery. It is now realised that these fears are not justified.

Elderly patients with major trauma may be considered a more challenging cohort to manage (in both the assessment, anaesthesia and the reconstructive surgery), compared to the paediatric population. Comorbidities bring frailty with increasing age. It fluctuates and varies with acute exacerbations of illnesses. Quantification of frailty to a meaningful number or index would help clinicians tailor personalised care. When an elderly patient suffers trauma, their frailty may become difficult to measure. In an acute hospital settings; therefore, it is prudent to identify baseline frailty status of such patient so that coordinated and individualised care is provided both in the hospital and in the community. It also has the potential of bridging fragmentation between primary and secondary care. Currently, we do not have such stratification tools in practice but we are working to fulfil this recommendation from NICE (2016). There are 2 groups of frailty assessment tools available - those validated for stable patients in primary care (electronic frailty index-eFI and Rockwoods Clinical Frailty score) [35] and those validated for use in the acute setting within secondary care (Prisma 7/ Timed get up and go/ Gait speed). Most primary care trusts in England are now using the eFI. The eFI stratifies frailty in to mild, moderate or severe and assigns a number which is highlighted in the patients care record and is available online. The clinical relevance of the eFI needs further clinical trials are needed. This may ultimately allow treating surgeons to make clinical decisions and the suitability for treatment. There are no scores for the inherently complex reconstructive intervention such as Orthoplastics. Such tool/indices would be very beneficial in decision-making and signposting targeted outcomes in terms of quality of life and functioning.

Whilst there are challenges associated with the elderly patients' journey, including the anaesthetic and post-operative complications [36,37] there is evidence to support aggressive management of severe open fractures in the elderly group [38].

IIIB injuries are, by definition, not possible to close primarily. However, some studies have stated that some of the IIIB fractures in their cohort were closed primarily [34], while a recent study suggested that free flap reconstruction was only required in 1 out of 43 paediatric grade III injuries [12]. Joint consultant decisions improve the quality of assessment of the soft tissues and reduce the risk of inappropriate debridement due to over-reliance on healing potential in children, or fear of poor healing in the elderly and hence conservative preponderance.

We observed good compliance with BOA/BAPRAS target timelines in both the paediatric and elderly groups, unless there was a delay in referring or transferring the patient to our unit, as has been highlighted in previous work [39]. Medical optimization prior to fix and flap can occasionally lead to deviation from the recommended timeline which may be the lesser risk to the patient.

Microsurgery in children has been debated for its reliability and technical challenges. Early studies suggested that flap failures were more frequent with smaller vessel size, perhaps related to vessel spasm [40,41]. However, more recent studies have refuted vasospasm as a factor, due to an underdeveloped muscularis layer in children [42]. The same study also highlights the importance of post- operative immobilization for microsurgical success. Poor compliance to bed rest and elevation of the limb was the cause of our only free flap failure in this age group. Furthermore, there is now evidence from many studies, that microsurgery is safe and has a high success rate in the paediatric population [43–45]. Our study echoes these reports.

Microsurgery in the elderly is also a challenge but for different reasons. In the elderly, there will be some degree of vessel atherosclerosis making microsurgery technically and physiologically less predictable. A preoperative CT angiogram, when possible, is a pre-requisite in our practice. It helps define arterial injury, premorbid stenosis, or anatomical variants, and helps in microsurgical planning.

The majority of our paediatric group required free flap reconstruction with cutaneous flaps. This was due to the injuries being high energy and therefore the poor reliability of local tissue to provide robust vascularised cover. The use of skin flaps avoids the potential donor morbidity of sacrificing a muscle, and also reduces the need for skin grafting and the potential complications described by Chiang et al [46]. It remains unclear whether free tissue transfer interferes with growth in children. Iwava et al proposed that it affects the growth of the transferred tissue whereas Canales et al. found no such effect [41,47]. Chiang et al recommend avoiding total harvest of the latissimus dorsi flap in children to avoid a growth asymmetry of the shoulders. As has previously been reported, we find that skin flaps are more resilient if revision surgery is required [31,48].

Our elderly population also underwent free flap reconstruction with a similar preponderance for skin flaps, if local tissues were not reliable. However, there were a higher proportion of loco-regional flaps used. This reflects the low energy transfer of the injury and therefore the availability of reliable loco-regional donor sites. The pedicled medial plantar flap has become a workhorse reconstruction in our unit for low-energy open ankle fractures, in the frail elderly, with a burst laceration over the medial malleolus. We have found this reconstructive option to be quick, and reliable. While mild gait changes have previously been reported [49], many of our patients undergo a hindfoot nail procedure, which will affect their gait in any case. However, it seems to be well tolerated in this age group, according to their Enneking functional scores.

The method of fixation was orthopaedic surgeon's preference with relative considerations for each group. This took into account the need for early mobilisation (especially the elderly) and the need to preserve growth potential in the paediatric group. Thus, the technique chosen was predominantly IM nailing in the elderly group, and circular frame (Taylor Spatial Frame) in children. Each of these techniques have been reported to be safe with reliable outcomes and low complication rates [50,51].

All our patients were managed according to a strict post-operative flap protocol, whether their soft tissue reconstruction was free tissue transfer or a loco-regional pedicled flap reconstruction (Graph 2). Although our pathway aims to discharge patients a week after definitive reconstruction, our data demonstrates that there can be delays in discharge for both of these age groups. The main reasons relate to social issues and the need to discharge vulnerable patients safely. The elderly patients were frequently repatriated for further rehabilitation in a hospital closer to their home. Chiang et al recorded mean hospital stays of 32 days and acknowledge the challenges of recovering a paediatric patient post microsurgical reconstruction [46]. Our paediatric group benefitted from the input of specialist nurses, physios and play specialists both in hospital and in the community to achieve discharge to their own home in a relatively short time.

The median time to fracture union was 144 days in the paediatric group and 150 days in the elderly group. This similarity

in the time to union despite the age difference may be due to the differing scales of energy transfer in the two separate groups – High energy injuries in children with excellent healing potential versus low energy injuries in the elderly but with poor healing potential. The rate of deep infection was 0% and 1% in paediatric and elderly age group respectively. This is lower than is quoted in the literature, but may simply reflect the relatively small sample size of this series, as our previously published infection rate in IIIB open tibial fractures was 4% for fix and flap procedures [23]. There will be occasions when acute bone shortening to allow primary closure after wound excision is the only option and must be considered.

Only one of our patients (elderly) requested an amputation. Our paediatric patients returned to a median of 85% function on Enneking score and our elderly group achieved 70% function. These figures demonstrate that our paediatric patients rehabilitate well, even after high-energy injuries. As could be expected, our elderly patients find rehabilitation more difficult, even after low-energy falls. While we acknowledge that the Enneking Patient Reported Outcome Measure (PROM), does not give a comprehensive picture of patients' function, it is a useful tool in our practice [52,53]. We found it was possible to use in our paediatric patients with occasional input from parents in the very young. It was also not possible to use in elderly patients with significant cognitive impairment.

There are a number of other potential limitations and confounding factors in this study that are worthy of further discussion. The outcomes presented in this study depend on a well-developed orthoplastic infrastructure at our MTCs and well-defined trauma pathways within our trauma network. It should be acknowledged that these facilities are often not available in other centres nationally, or globally. We have a defined and developed care pathway for all open lower limb fractures, which makes management of such patients more predictable and coherent. Our short length of stay for the elderly does not encompass entire rehabilitation due to repatriation to other hospitals, and we are unable to provide full data on when these patients were discharged from their local trauma unit. Some patients were lost to follow-up prior to 6 months, either due to deaths in the community or failure to attend combined orthoplastic clinics. While old age is associated with frailty, ASA grading is not the most comprehensive method of assessing frailty [54].

Future work on this subject should consider the introduction of a frailty score. A number of different models of frailty, screening tools and scoring indices have been proposed in the community and acute hospital setting [55–58]. The use of such indices at the time of the patient's presentation to the Emergency Department, and in conjunction with an Orthogeriatric assessment, could expedite optimization of the patient pre-operatively, influence surgical plans, and improve rehabilitation pathways in the Major Trauma Centre and the wider community; thus, reducing intensive care stays and ultimately facilitating timely and safe discharge plans.

Conclusion

The challenge of lower extremity trauma management is complex and varied. Despite abundant published literature discussing adult injured patients, drawing clear conclusions for extremely young or old age patients, is an arduous undertaking. For patients at the extremes of age, the evidence remains scanty and standards undrawn. In the UK, BOA/BAPRAS standards of care and NICE guidelines have improved outcomes and encouraged nationwide uniformity of care. Patients are unique, their injuries diverse, their needs varied and their outcomes personalised, however, we demonstrate adherence to key standards is rewarding and reproducible in achieving patient tailored outcomes and low complication rates even at extremes of ages. We believe that whilst national guidelines are important for the population in general, deviations can allow for the elderly frail patients. Free tissue transfer remains the cornerstone of soft tissue reconstruction in all age groups.

Conflict of interest statement

The authors do not have any conflict of interest and there were no funding required for this paper.

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