Journal of Clinical Orthopaedics and Trauma 34 (2022) 102029

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

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

Radiation exposure from fluoroscopy during tibia fracture intramedullary nailing – The effect of surgical experience

Jessica Jobson [a, *], Ahmed Saad [a], Ibrahim Jaly [a], Ravneet Singh [b], Khalid Baloch [a], Rajesh Botchu [c]

[a] Department of Trauma & Orthopaedic Surgery, Queen Elizabeth Hospital Birmingham, UHB, Mindelsohn Way, Birmingham, B15 2GW, UK
[b] Department of Radiology, Queen Elizabeth Hospital Birmingham, UHB, Mindelsohn Way, Birmingham, B15 2GW, UK
[c] Department of Radiology, Royal Orthopaedic Hospital, Birmingham, Bristol Rd S, Northfield, Birmingham, B31 2AP, UK

ARTICLE INFO

Article history:
Received 13 April 2022
Received in revised form
30 July 2022
Accepted 18 September 2022
Available online 28 September 2022

1. Introduction

Tibial fractures are the most prevalent long bone injuries, with an estimated incidence of 16.9/100,000/year.[1] These can be associated with both short and long term morbidities, which may have a significant impact on a patient's mobility and quality of life.[2] Therefore, appropriate management is critical in determining patient outcomes (see Tables 4 and 5).

With the modern concepts and enthusiasm in minimally invasive surgery, the current treatment of choice for tibial fractures is intramedullary Nailing (IMN).[3–6] This procedure has been shown to reduce infection rates, decrease rotational malalignment, allow early mobilisation and reduce time to fracture union, in comparison with other fixation methods.[4,6]

With less anatomical exposure, IMN requires intraoperative fluoroscopic guidance for fracture reduction, guide-wire insertion and distal locking. The risks imposed by ionising radiation are vast[7,8] and can lead to stochastic and deterministic effects.[9,10] It is, therefore, imperative that surgeons understand different methods of minimising radiation exposure (RE) and aim to follow the ALARA principle – As Low as Reasonably Achievable.[11] Factors that influence RE include: surgeons' experience, fluoroscopy positioning in respect to the patient and operating team, as well as protective cover donning.

This study was performed to identify the total RE in IMN for tibial fractures, taking into account the level of surgical experience and other confounding factors that influence RE. We also provide up to date recommendations, based on the literature, to minimise RE risk.

2. Methods

We performed a retrospective study within a Major Trauma Centre, looking into all IMN procedures for diaphyseal tibial fractures performed during the period of September 01, 2020 to December 31, 2021. We included all diaphyseal tibial fractures meeting the inclusion criteria and identified eligible patients at our hospital using trauma take admission lists and theatre lists.

The data compiled included:

- Date
- Procedure
- Primary Surgeon
- Level of experience
- Dose (Gy/cm2)
- Fluoroscopy time
- Open vs Closed Fractures
- Surgical Approach
- AO Fracture classification
- Method of Reduction
- Distal Locking Technique

* Corresponding author.
E-mail address: jess.jobson@hotmail.co.uk (J. Jobson).

https://doi.org/10.1016/j.jcot.2022.102029
0976-5662/© 2022 Delhi Orthopedic Association. All rights reserved.

Furthermore, the primary surgeons' level of operative experience was categorised into three groups (Table 1) - Consultants (>8 years' experience) were included in group I, senior registrars (6–8 years experience) in group II and junior registrars (1–5 years experience) in group III.

All intraoperative imaging was performed using a mobile C-arm fluoroscopy unit (Philips Libra, Philips Medical Systems, Best, The Netherlands). To assess the RE in each procedure, we calculated the dose area product (DAP), measured in Gy cm2 for each patient. The DAP is currently the most accepted method in quantifying RE in diagnostic X-RAY procedure, described in the National Protocol for Patient Dose Measurement in Diagnostic Radiology.[12]

We used IBM SPSS Statistics ver. 23.0 (SPSS Inc, Chicago, IL, USA) for statistical analysis with p value of less than 0.05 considered to be significant. Furthermore, Independent samples *t*-test and ANOVA was used to compare our means.

This study was approved by our local research and audit department.

3. Results

A total of 102 patients with fluoroscopically assisted IMN fixation were included within our cohort. There was a slight male predominance with a ratio of ~1.1 to 1 (53 males and 49 females). The average age of our patients was 44 years (range 17–91 years).

Of the 102 procedures undertaken, 63 cases were performed by group I, 17 by group II and 22 were by group III.

The average RE (Gy-cm2) during these procedures was 2.38 (range 0.01–13.07). When considering each group: group I had an average RE of 2.46 (range 0.017–13.07), group II was 2.42 Gy-cm2 (range 1.12–5.1) and group III was 2.14 (range 0.01–7.35) (Table 1). When undertaking an independent sample *t*-test, we could not identify any statistical significance between the level of surgical experience and RE across all the groups (p-value of .65) (see Table 6).

All the fractures were classified using the Müller AO Classification,[13] and the total number of cases across each subtype is highlighted in Tables 7–8. We identified no significant difference between the complexity of the fracture, surgical experience and radiation exposure across all three groups.

The suprapatellar approach was the most common approach used across all groups (n = 61), with an average radiation dose of 2.13 Gy-cm2 across our cohort. The infrapatellar approach was used in the remaining 41 cases, with an average radiation dose of 2.23 gycm2. We could not find any statistical significance between an increase in RE and type of approach (P-value of .11). These results are highlighted in Table 1.

With regards to the reduction technique used to stabilise fractures prior to IMN insertion, 72% of surgeons preferred using standard Manual reduction (MR). Adjunctive reduction aids were used in the remaining 28%. These included a half frame (n = 15), open/closed clamp reduction (n = 10), STORM device (n = 4), as well as a femoral distractor in only once case. Taking RE into account, using the half-frame yielded the lowest average radiation dose (1.8 Gycm2), whereas MR was related to the highest RE with a mean of 2.8 Gycm2. All of the surgeons used a freehand distal locking technique. (Tables 1 and 2). (see Table 3)

Table 1
Average Radiation doses within our Cohort.

	Total Number	Avg Radiation Dose
Approach		
Suprapatella	61	2.13
Infrapatella	41	2.23
P Value RE Suprapatellar vs Infrapatellar		***0.11***
Distal Screw Technique		
Freehand	102	2.38
Other	0	0
Fracture Subtype		
Open	16	2.32
Closed	86	2.4
Reduction Technique		
Syn Ream/Wire	72	2.8 HIGHEST
Closed Clamp Reduction	3	1.58
Open Reduction	7	2.47
STORM	4	2.32
Half Frame	15	1.8 LOWEST
Femoral Distractor	1	0.96

4. Discussion

Image intensifiers are used judiciously to guide intraoperative fixations for many different procedures within the field of Trauma & Orthopaedics. Multiple studies have demonstrated a significant increase in the incidence of malignancies in Orthopaedic surgeons, likely related to intraoperative RE.[14] IMN, a fluoroscopic guided procedure, remains the gold standard technique for diaphyseal tibia fracture fixation. As far as the authors are aware, this is one of a few rare studies, looking at the effect of surgical experience on RE and screening time during fluoroscopically assisted IMN of tibia fractures.

From the literature, we know that the relationship between surgical experience and RE has previously been investigated when considering a range of other operative procedures. Botchu et al.[15] Giannoudis et al.[16] and Quah et al.'s[17] studied this relationship in neck of femur (NOF) fracture fixations and found that, in contrast to our study, the radiation doses during hip surgery were far greater when performed by junior surgeons, compared with surgeons who had more than 10 years of surgical experience. Although the conclusions they reached were meaningful, it's important to recognise that NOF fixations, from a technical standpoint, can differ in several ways from IMN of tibia fractures and this can lead to variations in RE. For example, excessive fluoroscopy during IMN fixations can be influenced by the surgical approach, method of fracture reduction, nail insertion, and distal locking techniques.

Adequate fracture reduction allows the operating surgeon to proceed proficiently with the procedure, reducing operative times and radiation doses. A few studies have looked into the outcomes of device-assisted reduction before IMN of tibia fractures.[18–21] Traditional methods include traveling traction, the use of percutaneous clamps and blocking screws, either in isolation or as a combined technique. More recently, the use of the STORM device and a simple frame have come into fashion.[22] The latter technique has been reported to provide better outcomes in terms of fracture reduction; reducing both operative and screening times.[23] Although our study revealed no statistical significance between the different reduction methods across the three groups, we did notice a reduction in the overall radiation dose when a half-frame was utilised.

The surgical approach to IMN is another important factor that impacts RE. The intricate differences between each of the approach techniques described can be comprehensive and are beyond the scope of this study. However, in general, the approach to IMN has a direct effect in achieving and maintaining fracture reduction, as well as nail instrumentation.[24] The infrapatellar approach is the traditional method of IMN and can further be subdivided into a parapatellar or through patella tendon approach.[25] The suprapatellar approach has recently become more popular, and furthermore, has been shown to significantly reduce the surgical time and fluoroscopy use, hence the total radiation dose to both surgeons and patients.[26]

In addition, distal locking has been depicted as the most

Table 2
Average RE - Group I Vs Group II + III (Consultants vs Registrars).

RADIATION DOSE (Gy-cm2)		
	Consultants	Registrars
Approach		
Suprapatella	2	2.95
Infrapatella	3.09	2.28
Distal Screw Technique		
Freehand	2.45	2.28
Other	0	0
Fracture Subtype		
Open	1.95	2.27
Closed	2.55	2.33
Reduction Technique		
Syn Ream/Wire	2.8	1.45
Closed Clamp Reduction	1.58	0
Open Reduction	2.66	3.19
STORM	1.289	0
Half Frame	2.315	3.405
Femoral Distractor	0.96	0
External Fixation		
Yes	2.145	2.82
No	2.57	2.07

The p-value is .625321. The result is not significant at $p < .05$.

Table 3
Average RE between II & III (Senior vs Junior Registrars).

RADIATION DOSE (Gy-cm2)		
	Junior Reg	Senior Registrars
Approach		
Suprapatella	3.56	2.34
Infrapatella	2.41	2.15
Distal Screw Technique		
Freehand	2.14	2.42
Other	0	0
Fracture Subtype		
Open	2.27	2.26
Closed	2.33	2.55
Reduction Technique		
Syn Ream/Wire	1.45	2.15
Closed Clamp Reduction	0	0
Open Reduction	3.19	3.95
STORM	0	0
Half Frame	3.405	4.93
Femoral Distractor	0	0
External Fixation		
Yes	2.54	3.1
No	1.92	2.21

The p-value is .596698. The result is not significant at $p < .05$.

challenging part of the procedure, as it necessitates the need to shape 'the perfect circles' on fluoroscopic imaging, as well as accurately positioning the drill to ensure it passes directly through the distal holes. This can often take a substantial amount of time and number of attempts, increasing overall RE.

Numerous techniques have been established to guide distal locking screw insertion; however, the freehand approach remains to be the most popular method used.[27] Other proposed methods include the use of a radiolucent drill or an electromagnetic navigation system, both of which have been proven to improve fluoroscopy time and overall radiation dose.[28]

Lastly, other important non-surgical factors that reduce RE during these procedures include the use of personal protective equipment and patient positioning. PPE, in the form of lead and thyroid aprons, gloves and eye-protective wear has been shown to reduce radiation dosages by over 90%.[29] Moreover, it is proposed that patients positioned close to the image intensifier reduce the amount of scatter radiation to both the patient and theatre personnel.[30,31]

The crux of our paper was to understand the effect of surgeon experience on radiation exposure. Whilst this is a seldom discussed consideration, it is no doubt an important one. Training grade surgeons, particularly higher surgical trainees, often build their surgical proficiency and experience while performing IMN of tibia fractures.[32] Moreover, IMN is an index procedure that is essential for orthopaedic trainees to demonstrate competencies before completion of training. Their lower levels of experience may theoretically translate into longer screening times and higher RE, especially during more challenging phases of the operation e.g. distal locking (as previously described). With this in mind, junior trainees may, therefore, be tasked with undertaking more 'straightforward' procedures with simple fracture patterns. The opposite is also likely to be true, with senior surgeons/consultants taking on the complex and difficult cases deemed unsuitable for training. Despite this, our study shows no significant difference in radiation exposure during tibia IMN regardless of the surgical experience, complexity of fracture or procedure approach.

Table 4
Average Radiation Exposure in Group I (Consultants with >8 year's experience).

	Total Number	Avg Radiation Dose (Gy-cm2)
Approach		
Parapatella	27	3.09 HIGH
Suprapatella	37	2 LOW
Distal Screw Technique		
Freehand	63	2.45
Other	0	0
Fracture Subtype		
Open	10	1.95
Closed	53	2.55
Reduction Technique		
Syn Ream/Wire	41	2.8 HIGHEST
Closed Clamp Reduction	3	1.58
Open Reduction	5	2.66
STORM	4	1.289 LOWEST
Half Frame	9	2.315
Femoral Distractor	1	0.96
External Fixation		
Yes	17	2.145
No	46	2.57

Table 5
Average RE in Group II (Senior registrars).

	Total Number	Avg Radiation Dose (Gy-cm2)
Approach		
Suprapatella	10	2.34
Infrapatella	7	2.15
Distal Screw Technique		
Freehand	63	2.42
Other	0	0
Fracture Subtype		
Open	1	2.26
Closed	16	2.55
Reduction Technique		
Syn Ream/Wire	15	2.15 LOWEST
Closed Clamp Reduction	0	0
Open Reduction	1	3.95
STORM	0	0
Half Frame	1	4.93 HIGHEST
Femoral Distractor	0	0
External Fixation		
Yes	4	3.1
No	13	2.21

Table 6
Average RE in Group III (Junior registrars).

	Total Number	Avg Radiation Dose (Gy-cm2)
Approach		
Suprapatella	14	3.56 HIGH
Infrapatella	8	2.45 LOW
Distal Screw Technique		
Freehand	63	2.14
Other	0	0
Fracture Subtype		
Open	5	2.28
Closed	16	2.1
Reduction Technique		
Syn Ream/Wire	16	2.21
Closed Clamp Reduction	1	0
Open Reduction	1	2.44
STORM	0	0
Half Frame	5	1.88 LOWEST
Femoral Distractor	0	0
External Fixation		
Yes	8	2.54
No	14	1.92 LESS

Table 7
Total Number of Fracture subtypes (Based on AO Classification) across three groups.

AO Classification Subtype	N		
	GROUP I	GROUP II	GROUP II
A1 simple spiral	33	6	9
A2 Simple oblique	4	0	4
A3 Simple transverse	7	1	1
B1 Spiral wedge	3	1	1
B2 Bending wedge	4	2	3
B3 fragmented wedge	2	1	1
C1 Complex spiral	3	2	0
C2 complex segmental	3	2	2
C3 complex irregular	4	1	1
Unable to classify	0	1	1

The p-value is .17462. The result is not significant at $p < .05$.
No significance between complexity of fracture and level of experience across all three groups.

Table 8
Average Radiation doses (Gy-cm2) according to the complexity of the Fracture.

AO Classification	N of cases	Average Radiation dose (Gy-cm2)
A1 simple spiral	47	2.18
A2 Simple oblique	8	2.57
A3 Simple transverse	10	2.62
B1 Spiral wedge	5	2.42
B2 Bending wedge	9	2.73
B3 fragmented wedge	4	2.03
C1 Complex spiral	5	2.79
C2 complex segmental	6	2.55
C3 complex irregular	6	2.94
Unable to classify N/A	2	1.08

The p-value is .076859. The result is not significant at $p < .05$.
No significance between complexity of fracture and radiation dose per procedure.

Nonetheless, the associated risks of this must be balanced against the training needs of the surgeon as they attempt to gain practical expertise.

5. Limitations

It is important to note that there are several limitations to this study. Firstly, it is difficult to obtain the data showing the proximity of individuals during procedures in relation to radiation exposure, which may act as a confounding factor.

Moreover, it was difficult to isolate the amount of radiation utilised during distal locking, which may act as a confounding factor to the total amount of radiation dose used throughout the procedure. Finally, although we did not find any statistical significance between radiation exposure and reduction techniques, our case numbers for these adjuncts were relatively low. This, however, was not the sole purpose of the study. Further research is required to specifically analyse the degree of radiation exposure in correlation to different pre adjunctive reduction methods for IMN.

6. Conclusion

The results of our study indicate that RE to healthcare professionals from fluoroscopy use during tibia intramedullary nailing is not directly related to surgical experience. Surgeons should be aware of the different factors that may influence RE; including fracture patterns, surgical approaches and distal locking techniques.

CRediT authorship contribution statement

J. Jobson: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization,

Supervision. **A.I. Saad:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Formal analysis. **I. Jaly:** Writing – original draft, Formal analysis. **R. Singh:** Formal analysis. **K. Baloch:** Supervision. **R. Botchu:** Writing – review & editing, Formal analysis, Supervision.

References

1. Larsen P, Elsoe R, Hansen SH, Graven-Nielsen T, Laessoe U, Rasmussen S. Incidence and epidemiology of tibial shaft fractures. *Injury*. 2015;46(4):746–750. https://doi.org/10.1016/j.injury.2014.12.027.
2. Waddell JP, Reardon GP. Complications of tibial shaft fractures. *Clin Orthop Relat Res*. 1983;178:173–178.
3. Thompson JH, Koutsogiannis P, Jahangir A. Tibia fractures overview. In: Treasure Island (FL): StatPearls Publishing; 2022.
4. Grubor P, Grubor M, Tanjga R, Mitković MM. Dilemmas in the treatment of tibial diaphyseal fractures. *Acta Chir Iugosl*. 2013;60(2):33–39. https://doi.org/10.2298/aci1302033g.
5. Konrath G, Moed BR, Watson JT, Kaneshiro S, Karges DE, Cramer KE. Intramedullary nailing of unstable diaphyseal fractures of the tibia with distal intraarticular involvement. *J Orthop Trauma*. 1997 Apr;11(3):200–205. https://doi.org/10.1097/00005131-199704000-00011.
6. Yavuz U, Sökücü S, Demir B, Yıldırım T, Ozcan C, Kabukçuoğlu YS. Comparison of intramedullary nail and plate fixation in distal tibia diaphyseal fractures close to the mortise. *Ulus Travma Acil Cerrahi Derg*. 2014 May;20(3):189–193. https://doi.org/10.5505/tjtes.2014.92972.
7. Srinivasan D, Than KD, Wang AC, et al. Radiation safety and spine surgery: systematic review of exposure limits and methods to minimize radiation exposure. *World Neurosurg*. 2014;82:1337–1343. https://doi.org/10.1016/j.wneu.2014.07.041.
8. Blakely EA. Biological effects of cosmic radiation: deterministic and stochastic. *Health Phys*. 2000;79:495–506. https://doi.org/10.1097/00004032-200011000-00006.
9. Morgan WF, Day JP, Kaplan MI, et al. Genomic instability induced by ionizing radiation. *Radiat Res*. 1996;146:247. https://doi.org/10.2307/357945.
10. Jenkins NW, Parrish JM, Sheha ED, Singh K. Intraoperative risks of radiation exposure for the surgeon and patient. *Ann Transl Med*. 2021;9(1):84. https://doi.org/10.21037/atm-20-1052.
11. Report No. 107 National Council on Radiation Protection and Measurements. *Implementation of the Principle of as Low as Reasonably Achievable (ALARA) for Medical and Dental Personnel*. NCRP Publications; 1990. ISBN 0-929600-15-0.
12. Dosimetry Working Party of the Institute of Physical Sciences in Medicine. *National Protocol for Patient Dose Measurements in Diagnostic Radiology*. Chilton: NRPB; 1992.
13. Müller ME, Nazarian S, Koch P. *Classification AO des fractures. Tome I. Les os longs*. Berlin: Springer-Verlag; 1987.
14. Mastrangelo G, Fedeli U, Fadda E, Giovanazzi A, Scoizzato L, Saia B. Increased cancer risk among surgeons in an orthopaedic hospital. *Occup Med (Lond)*. 2005;55:498–500. https://doi.org/10.1093/occmed/kqi048.
15. Botchu R, Ravikumar K. Radiation exposure from fluoroscopy during fixation of hip fracture and fracture of ankle: effect of surgical experience. Oct-Dec *Indian J Orthop*. 2008;42(4):471–473. https://doi.org/10.4103/0019-5413.43398.
16. Giannoudis PV, McGuigan J, Shaw DL. Ionising radiation during internal fixation of extracapsular neck of femur fractures. *Injury*. 1998 Jul;29(6):469–472. https://doi.org/10.1016/s0020-1383(98)00090-4.
17. Quah C, Mehta R, Shivji FS, et al. The effect of surgical experience on the amount of radiation exposure from fluoroscopy during dynamic hip screw fixation. *Ann R Coll Surg Engl*. 2017 Mar;99(3):198–202. https://doi.org/10.1308/rcsann.2016.0282.
18. Beazley JC, Hull P. Temporary intra-operative reduction techniques for tibial fracture fixation: a review of the literature. *Injury*. 2010;41:1228–1233. https://doi.org/10.1016/j.injury.2010.07.250.
19. Forman JM, Urruela AM, Egol KA. The percutaneous use of a pointed reduction clamp during intramedullary nailing of distal third tibial shaft fractures. *Acta Orthop Belg*. 2011;77:802–808.
20. Moed BR, Watson JT. Intramedullary nailing of the tibia without a fracture table: the transfixion pin distractor technique. *J Orthop Trauma*. 1994;8:195–202. https://doi.org/10.1097/00005131-199406000-00003.
21. Krettek C, Stephan C, Schandelmaier P, et al. The use of Poller screws as blocking screws in stabilising tibial fractures treated with small diameter intramedullary nails. *J Bone Joint Surg Br*. 1999;81:963–968. https://doi.org/10.1302/0301-620x.81b6.10000.
22. Mehta N, Selvaratnam V, Giotakis N, Narayan B. Is device-assisted reduction prior to semi-extended intramedullary nailing of distal tibial fractures necessary? *Injury*. 2017 Feb;48(2):506–510. https://doi.org/10.1016/j.injury.2016.12.002.
23. Cj, Atkins RM. Fine wire frame-assisted intramedullary nailing of the tibia. *J Orthop Trauma*. 2003 Mar;17(3):222–224. https://doi.org/10.1097/00005131-200303000-00012.
24. Williamson M, Iliopoulos E, Williams R, Trompeter A. Intra-operative fluoroscopy time and radiation dose during suprapatellar tibial nailing versus infrapatellar tibial nailing. *Injury*. 2018 Oct;49(10):1891–1894. https://doi.org/10.1016/j.injury.2018.07.004.
25. Zelle B, Boni G. Safe surgical technique: intramedullary nail fixation of tibial shaft fractures. *Patient Saf Surg*. 2015;9:40. https://doi.org/10.1186/s13037-015-0086-1.
26. Gao Z, Han W, Jia H. Suprapatellar versus infrapatellar intramedullary nailing for tibial shaft fractures. *Medicine (Baltimore)*. 2018 Jun;97(24), e10917. https://doi.org/10.1097/MD.0000000000010917.
27. Moor B, Ehlinger M, Arlettaz Y. Distal locking of femoral nails: mathematical analysis of the appropriate targeting range. *Orthop Traumatol Surg Res*. 2012;98(1):85–89. https://doi.org/10.1016/j.otsr.2011.08.010.
28. Grimwood D, Harvey-Lloyd J. Reducing intraoperative duration and ionising radiation exposure during the insertion of distal locking screws of intramedullary nails: a small-scale study comparing the current fluoroscopic method against radiation-free, electromagnetic navigation. *Eur J Orthop Surg Traumatol*. 2016 Dec;26(8):867–876. https://doi.org/10.1007/s00590-016-1835-2.
29. International Atomic Energy Agency. Radiation protection of medical staff in interventional procedure [Internet]. [Updated 2022.03.09]. Available from: https://www.iaea.org/resources/rpop/health-professionals/interventional-procedures/radiation-protection-of-medical-staff-in-interventional-fluoroscopy.
30. Jenkins NW, Parrish JM, Sheha ED, Singh K. Intraoperative risks of radiation exposure for the surgeon and patient. *Ann Transl Med*. 2021 Jan;9(1):84. https://doi.org/10.21037/atm-20-1052.
31. Hayda RA, Hsu RY, DePasse JM, Gil JÁ. Radiation exposure and health risks for orthopaedic surgeons. *J Am Acad Orthop Sur*. 2018 Apr 15;26(8):268–277. https://doi.org/10.5435/JAAOS-D-16-00342.
32. Bowditch M, Ryan W, Gregory R. Speciality advisory committee for trauma and orthopaedic surgery. ISCP [Internet]. [Updated 2021.08.04]. Available at: https://www.iscp.ac.uk/media/1114/trauma-orthopaedic-surgery-curriculum-aug-2021-approved-oct-20.pdf/.