ating the studies that included only post-infective bone defects it is noteworthy that there was recurrence of infection in two out of 17 cases in which PMMA without antibiotics was used, [19] compared to no recurrence in 58 cases in which ABI spacers were used [5–8]. Furthermore, the addition of antibiotics may not necessarily result in inferior bony healing with union reported in 100% of the cases in which ABI PMMA spacers were used. The heterogeneity of these studies, however, prevents drawing firm conclusions in this regard. The successful use of ABI spacers has, however, recently been corroborated in a larger series (involving 22 cases of acute post-traumatic defects and 21 post-infective defects) by Giannoudis et al., who reported an overall union rate of 93% and only one case of recurrent infection at 2-years follow-up.

Despite the promising results that have been achieved with ABI PMMA, the optimal composition of the spacers remains to be determined. Rathbone et al. examined the effect of 21 different antibiotics on the viability and osteogenic activity of osteoblasts. Amikacin, tobramycin and vancomycin were found to be the least cytotoxic agents [20]. No well-designed comparative clinical studies to asses different spacer compositions have yet been performed in the post-infective setting. The choice of antibiotic appears to be empirical in most studies and none have reported it is necessary to preoperatively determine the causative organism. The most popular composition appears to be 2 to 4 gm of vancomycin added to 40 gm of PMMA with or without gentamycin (or tobramycin) [5,6,10–12].

REFERENCES

[1] Klemm K. The use of antibiotic-containing bead chains in the treatment of chronic bone infections. Clin Microbiol Infect. 2001;7:28–31.
[2] Kanakaris NK, Tosounidis TH, Giannoudis PV. Surgical management of infected non-unions: an update. Injury. 2015;46 Suppl 5:S25–S32. doi:10.1016/j.injury.2015.08.009.
[3] Mouzopoulos G, Kanakaris NK, Kontakis G, Obakponovwe O, Townsend R, Giannoudis PV. Management of bone infections in adults: the surgeon's and microbiologist's perspectives. Injury. 2011;42 Suppl 5:S18–S23. doi:10.1016/S0020-1383(11)70128-0.
[4] Lima ALL, Oliveira PR, Carvalho VC, Cimerman S, Savio E, Diretrizes Panamericanas para el Tratamiento de las Osteomielitis e Infecciones de Tejidos Blandos Group. Recommendations for the treatment of osteomyelitis. Braz J Infect Dis. 2014;18:526–534. doi:10.1016/j.bjid.2013.12.005.
[5] McNally M, Nagarajah K. (iv) Osteomyelitis. Orthop Trauma. 2010;24:416–429. doi:10.1016/j.mporth.2010.09.004.
[6] Qiu XS, Chen YX, Qi XY, Shi HF, Wang JF, Xiong J. Outcomes of cement beads and cement spacers in the treatment of bone defects associated with post-traumatic osteomyelitis. BMC Musculoskelet Disord. 2017;18:256. doi:10.1186/s12891-017-1614-1.
[7] Morelli I, Drago L, George DA, Gallazzi E, Scarponi S, Romanò CL. Masquelet technique: myth or reality? A systematic review and meta-analysis. Injury. 2016;47 Suppl 6:S68–S76. doi:10.1016/S0020-1383(16)30842-7.
[8] Masquelet AC, Fitoussi F, Begue T, Muller GP. [Reconstruction of the long bones by the induced membrane and spongy autograft]. Ann Chir Plast Esthet. 2000;45:346–353.
[9] Masquelet AC. Induced membrane technique: pearls and pitfalls. J Orthop Trauma. 2017;31 Suppl 5:S36–S38. doi:10.1097/BOT.0000000000000979.
[10] Nau C, Seebach C, Trumm A, Schaible A, Kontradowitz K, Meier S, et al. Alteration of Masquelet's induced membrane characteristics by different kinds of antibiotic enriched bone cement in a critical size defect model in the rat's femur. Injury. 2016;47:325–334. doi:10.1016/j.injury.2015.10.079.
[11] Taylor BC, Hancock J, Zitzke R, Castaneda J. Treatment of bone loss with the induced membrane technique: techniques and outcomes. J Orthop Trauma. 2015;29:554–557. doi:10.1097/BOT.0000000000000338.
[12] J. Richard M, R. Creevy W, Tornetta P. The use of solid form-fitting antibiotic cement spacers in bone loss of the lower extremity. Current Orthop Practice. 2012;23:453–458. doi:10.1097/BCO.0b013e3182648c20.
[13] Kawakami R, Konno SI, Ejiri S, Hatashita S. Surgical treatment for infected long bone defects after limb-threatening trauma: application of locked plate and autogenous cancellous bone graft. Fukushima J Med Sci. 2015;61:141–148. doi:10.5387/fms.2015-17.
[14] Luo TD, Nunez FA, Lomer AA, Nunez FA. Management of recalcitrant osteomyelitis and segmental bone loss of the forearm with the Masquelet technique. J Hand Surg Eur Vol. 2017;42:640–642. doi:10.1177/1753193416650171.
[15] Scholz AO, Gehrmann S, Glombitza M, Kaufmann RA, Bostelmann R, Flohe S, et al. Reconstruction of septic diaphyseal bone defects with the induced membrane technique. Injury. 2015;46 Suppl 4:S121–S124. doi:10.1016/S0020-1383(15)30030-9.
[16] Wang X, Luo F, Huang K, Xie Z. Induced membrane technique for the treatment of bone defects due to post-traumatic osteomyelitis. Bone Joint Res. 2016;5:101–105. doi:10.1302/2046-3758.53.2000487.
[17] Marais LC, Ferreira N. Bone transport through an induced membrane in the management of tibial bone defects resulting from chronic osteomyelitis. Strategies Trauma Limb Reconstr. 2015;10:27–33. doi:10.1007/s11751-015-0221-7.
[18] Giannoudis PV, Harwood PJ, Tosounidis T, Kanakaris NK. Restoration of long bone defects treated with the induced membrane technique: protocol and outcomes. Injury. 2016;47 Suppl 6:S53–S61. doi:10.1016/S0020-1383(16)30840-3.
[19] El-Alfy BS, Ali AM. Management of segmental skeletal defects by the induced membrane technique. Indian J Orthop. 2015;49:643–648. doi:10.4103/0019-5413.168757.
[20] Rathbone CR, Cross JD, Brown KV, Murray CK, Wenke JC. Effect of various concentrations of antibiotics on osteogenic cell viability and activity. J Orthop Res. 2011;29:1070–1074. doi:10.1002/jor.21343.

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QUESTION 7: Should antibiotic cement rods (ACRs) be left permanently in situ?

RECOMMENDATION: If the ACR is used as a temporary non-locked implant for infection control, it should be removed and replaced by a biomechanically stable construct (e.g., locked intramedullary nail). If the ACR is used as a locked implant for both local delivery of antibiotics and provision of stable biomechanical conditions for consolidation of the non-union site, it can be left in place.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 70%, Disagree: 30%, Abstain: 0% (Super Majority, Weak Consensus)

RATIONALE

ACRs can be used for two different indications.

1. ACRs are used as non-locked temporary implants for the local delivery of antibiotics into the intramedullary canal to eradicate the infection. In cases with stable bone conditions, e.g., chronic osteomyelitis in long bones, missing rotational stability of the ACR is not relevant, whereas in infected non-unions with unstable bone conditions, the ACR is removed after infection control and replaced by a biomechanically stable implant, in most cases by a standard interlocking nail in a subsequent revision procedure.

For this indication, only technical notes, case reports and small case series with a maximum of 19 cases in one study exist [1–8]. In the 18-patient case series by Qiang et al., the mean indwelling time of the ACR was 57 days, ranging from 35 to 123 days [6]. Sancineto et al. published 19 cases with removal of the ACR between 6 and 76 weeks after surgery [7]. Badhra and Roberts reported some difficulties in

the removal of antibiotic nails that have been implanted for more than two months. They found that proximal incarceration of the nail requiring debridement of bone could occur and might need to be addressed using osteotomes [1]. Paley and Herzenberg also retained their cement-coated rods for up to 753 days without any major complication except rod fracture in one patient [5].

There is one study by Selhi et al. in which in some cases of unlocked ACRs were used for infected non-unions and these were retained for a longer period of time in order to achieve bone healing despite the absence of rotational stability. ACRs were kept for a period ranging from 6 weeks to 22 months with an average of 10.6 months [8]. These rods were usually retained until bony union occurred or secondary procedures like external fixation, intramedullary nailing, and/or bone grafting was performed.

2. ACRs can also be used as locked ACR with adequate biomechanical stability in infected long bone non-unions for both local delivery of antibiotics and provision of stable biomechanical conditions for consolidation of the non-union site [9–11]. For this indication, several retrospective case series (with a maximum of 110 cases in one study) exist. Good clinical outcomes with a healed uninfected bone in 105/110 patients (95%) was demonstrated [9]. Removal of the ACR was not reported in the articles and one can assume that the implants were left in place in order to not weaken the bone.

REFERENCES

[1] Bhadra AK, Roberts CS. Indications for antibiotic cement nails. J Orthop Trauma. 2009;23:S26–S30. doi:10.1097/BOT.0b013e31819f27aa.
[2] Madanagopal SG, Seligson D, Roberts CS. The antibiotic cement nail for infection after tibial nailing. Orthopedics. 2004;27:709–712.
[3] Mendicino RW, Bowers CA, Catanzariti AR. Antibiotic-coated intramedullary rod. J Foot Ankle Surg. 2009;48:104–110. doi:10.1053/j.jfas.2008.06.010.
[4] Ohtsuka H, Yokoyama K, Higashi K, Tsutsumi A, Fukushima N, Noumi T, et al. Use of antibiotic-impregnated bone cement nail to treat septic nonunion after open tibial fracture. J Trauma. 2002;52:364–366.
[5] Paley D, Herzenberg JE. Intramedullary infections treated with antibiotic cement rods: preliminary results in nine cases. J Orthop Trauma. 2002;16:723–729.
[6] Qiang Z, Jun PZ, Jie XJ, Hang L, Bing LJ, Cai LF. Use of antibiotic cement rod to treat intramedullary infection after nailing: preliminary study in 19 patients. Arch Orthop Trauma Surg. 2007;127:945–951. doi:10.1007/s00402-007-0315-x.
[7] Sancineto CF, Barla JD. Treatment of long bone osteomyelitis with a mechanically stable intramedullar antibiotic dispenser: nineteen consecutive cases with a minimum of 12 months follow-up. J Trauma. 2008;65:1416–1420. doi:10.1097/TA.0b013e31818c6a09.
[8] Selhi HS, Mahindra P, Yamin M, Jain D, De Long WG, Singh J. Outcome in patients with an infected nonunion of the long bones treated with a reinforced antibiotic bone cement rod. J Orthop Trauma. 2012;26:184–188. doi:10.1097/BOT.0b013e318225f77c.
[9] Conway J, Mansour J, Kotze K, Specht S, Shabtai L. Antibiotic cement-coated rods: an effective treatment for infected long bones and prosthetic joint nonunions. Bone Joint J. 2014;96-B:1349–1354. doi:10.1302/0301-620X.96B10.33799.
[10] Riel RU, Gladden PB. A simple method for fashioning an antibiotic cement-coated interlocking intramedullary nail. Am J Orthop. 2010;39:18–21.
[11] Thonse R, Conway J. Antibiotic cement-coated interlocking nail for the treatment of infected nonunions and segmental bone defects. J Orthop Trauma. 2007;21:258–268. doi:10.1097/BOT.0b013e31803ea9e6.

3.6. TREATMENT: WOUND COVERAGE

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QUESTION 1: Is there evidence to support one type of flap coverage over another (e.g., muscle over fasciocutaneous flap) after open tibial fractures?

RECOMMENDATION: Different types of flap coverage after open tibial fractures have essentially equivalent and comparable outcomes in terms of flap survival, bone healing, stress fracture, infection, chronic osteomyelitis and donor site morbidity. Local flaps should be considered in low energy trauma, when available. The type of flap should be tailored based on the extent and the depth of the soft tissue defect and the location of the fracture. In high energy fractures of the tibia, muscle flaps may offer a more reliable reconstruction with fewer flap failures and fewer reoperation rates.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 95%, Disagree: 5%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Multidisciplinary management of severe open tibial fractures with radical debridement, skeletal fixation and early stable coverage is essential for infection prevention and high-quality, cost-efficient trauma care [1]. The Gustilo-Andersen grading system of open tibial fractures is a significant prognostic factor of infectious complications and non-unions [2]. Open fractures of the tibia have a high incidence of infection and malunion [3,4]. Wound coverage does not only prevent wound desiccation and infection, but also contributes to fracture repair by serving as a local source of stem or osteoprogenitor cells, growth factors and vascular supply [5,6].

There is a growing body of evidence demonstrating that the biological characteristics of the tissues in a flap can significantly influence fracture healing, and the rate of delayed union or non-union. Timing of soft tissue coverage is also a critical determinant of the length of in-hospital stay and most of the early postoperative complications and outcomes [7]. Early coverage has been associated with higher union rates and lower complication and infection rates compared to those reconstructed after 5-7 days [2,5,7–9]. Furthermore, early reconstruction improves flap survival, as microsurgical free flap integration becomes more challenging with a delay due to an increased pro-thrombotic environment, tissue edema and the increasingly friable vessels. Only those patients presenting to facilities with an actual dedicated ortho-plastic trauma service are likely to receive definitive treatment of a severe open tibia fracture with tissue loss within the established parameters of good practice [7]. "Fix and flap" is being recommended for specialist hospitals where the expertise is available. Antibiotic bead pouches to decrease infection rates have been advocated when there is segmental tissue loss,