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Research Article

Intramedullary Nailing with an Absorbable Antibiotic Carrier (INaac): A Simple Technique Using Standard Implants

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Abstract

Introduction: Intramedullary nailing has revolutionized the treatment of long bone fractures and non-unions. However, there is rightly concern about the use of nails when there is established infection or when the risk of subsequent infection is high. Recently, this concern has been partly addressed by the introduction of intramedullary nails combined with an antibacterial coating. Various methods have been reported with some success but also with some drawbacks.

Methods: This paper reports a simple technique for coating an intramedullary nail with an absorbable antibiotic carrier. The carrier is injected directly into the reamed medullary canal, coating the nail during nail passage and delivering high levels of antibiotics at the nail-bone interface.

Results: This technique was found to be easy to apply. It allowed use of standard fracture implants without the need for downsizing of the nail diameter. There is no need for nail removal or exchange after initial treatment of the infection.

Conclusion: This simple technique combines the benefits of a bioabsorbable antibiotic carrier with standard fracture nails to prevent or treat long bone infections. It avoids the problems of PMMA coated nails or the need for specialist implants.

Keywords: Polymethylmethacrylate; Implants; Femoral Canal; Intramedullary Nail

Introduction

The use of intramedullary nails in the setting of non-union surgery is well established. Historically however, using intramedullary nails in the presence of infection has been considered high risk for persistent infection involving the new implant [1-3]. In these situations, surgeons are faced with not only the issue of fracture instability, but also that of achieving infection eradication. To combat this, techniques have been developed that allow intramedullary nails to be coated with Polymethylmethacrylate (PMMA) cement loaded with antibiotics [4,5]. This has the potential to deliver very high concentrations of antibiotics, without adverse systemic effects, while also removing concerns with compliance with treatment. However, potential issues with the use of PMMA coated nails include cement-nail debonding, nail preparation time and a potential reduction in the stability of the construct, with nail diameter sacrificed to allow appropriate cement mantel [6]. This issue with construct instability has typically been addressed with exchange nailing to a larger diameter nail once the infected non-union has been converted to a non-union without infection. The incidence of cement-nail debonding at exchange nailing is high, with further instrumentation of the canal required to clear this debonded cement. Furthermore, the use of PMMA as an antibiotic carrier is suboptimal for several reasons [5,7]. As the release of antibiotics relies on surface diffusion, the rate of release is influenced by the surface area of the PMMA coated nail. The antibiotic release is initially high for the first few hours post-operatively but quickly falls to lower, sub-therapeutic levels for a sustained period [5,8]. Prolonged low-level release of antibiotics below the minimum inhibitory concentration may cause multi-drug resistant organisms to predominate and once the antibiotic levels are sufficiently low the PMMA itself may become

colonized [9]. While the extensive surface area created by coating a nail allows a large area for surface diffusion, this also represents a large area for potential colonization.

In recent years, bioabsorbable antibiotic carriers have been investigated in prevention and treatment of fracture-related infections with encouraging results [1,9-11]. These materials have been proposed as possible antibiotic delivery systems in combination with intramedullary nails [5,12-14]. In this paper, we describe a simple technical guide to using an Intramedullary Nail, coated with an absorbable antibiotic carrier (INaac).

Technique

In cases of infected non-union, it is of paramount importance that adequate excision of all dead bone and biofilm is performed. Sinus tracts and implants must also be removed. A minimum of five samples are sent for microbiological analysis and three samples for histological analysis in order to confirm the diagnosis of infection and determine the causative pathogen [6,11,15]. Empiric systemic antibiotics are given following sampling. In our institution, debridement of the medullary canal is performed using sequential reaming to remove all membrane from the canal, followed by lavage with 0.05% aqueous chlorhexidine. Specialized combined reaming and irrigating equipment is not used. We often create a window in the distal part of the bone to remove reaming debris from the canal.

Once reaming and lavage is complete, the nail is selected (Fig. 1). Nail diameter in relation to final reamer size is based on surgeon preference. Usually, we will select a nail which is 1 mm smaller than the final diameter of reaming, to allow safe nail insertion. Of note, we do not downsize the diameter of the nail in order to provide a larger space for the antibiotic carrier; rather the largest diameter nail is chosen to maximize stability.

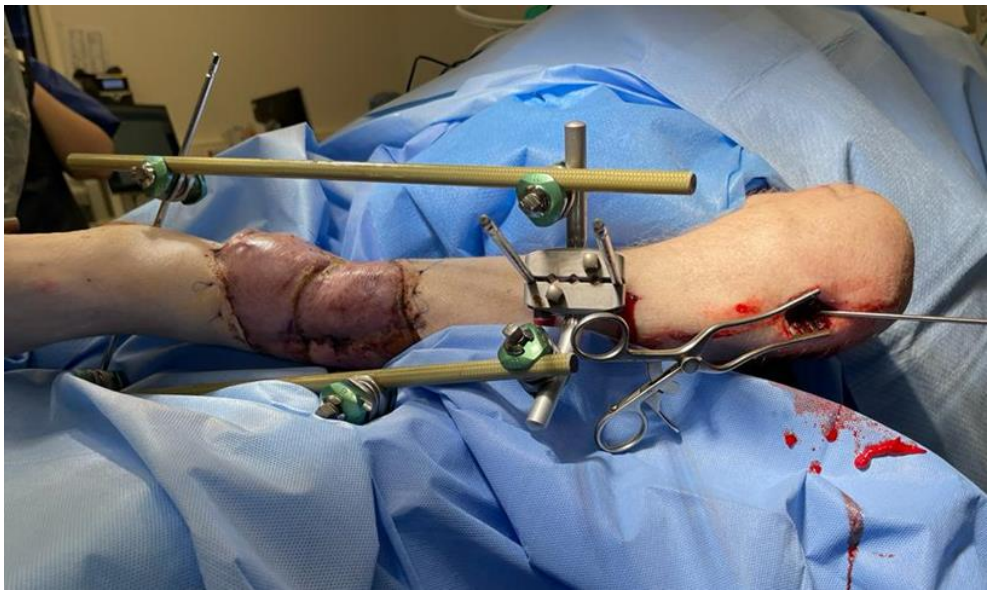

Figure 1: This patient suffered an open fracture of the lower tibia, initially treated with temporary external fixation and subsequent free flap after a short period with an open wound and negative pressure wound therapy. This presents a high risk of infection during conversion to intramedullary nail fixation.

In this technique, we advocate the use of a ceramic antibiotic carrier which can be injected into the canal, in liquid form, prior to nail insertion. The ceramic should set, without the production of heat, creating the nail coating *in-situ*. After reaming, 10 mls of the liquid, absorbable calcium sulphate/hydroxyapatite ceramic (Cerament; Bonesupport AB, Lund, Sweden) is prepared to the manufacturer's instructions. This ceramic carrier is provided with either Gentamicin (17.5 mg/ml) or Vancomycin (66 mg/ml). The surgeon may choose either antibiotic or mix both, depending on clinical need. Approximately half the mixture is then injected into the proximal part of the canal with the guidewire still *in-situ* (Fig. 2). On average, about 5 mls is required for a tibia and 8 mls for a femoral canal. It is not necessary to fill the entire canal as the volume of the residual space around the intramedullary nail is small.

Before the ceramic has set, the nail is then passed into the canal, through the liquid material, allowing self-coating of the nail surface and penetration of the ceramic into the surrounding bone (Fig. 3).

Figure 2: Liquid Cerament with gentamicin is injected into the proximal part of the tibial medullary canal, alongside the guide wire.

Figure 3: A standard tibial nail is inserted into the wet antibiotic carrier over the guide wire.

Once the nail has been passed, the guidewire and proximal jig are removed (Fig. 4). The remaining liquid ceramic is injected into the hollow interior of the nail itself, using a thin catheter. This coats the inner surface of the nail (Fig. 5). The nail is then impacted into the final position while the ceramic is still liquid. There is no concern about ceramic setting early during nail passage as this material does not set while it is being agitated or moved. Once movement ceases, it will set within 15 minutes.

Figure 4: The proximal jig and guide wire are removed to allow access to the lumen of the tibial nail. If the jig is cannulated, it may be possible to inject the material into the nail without jig removal.

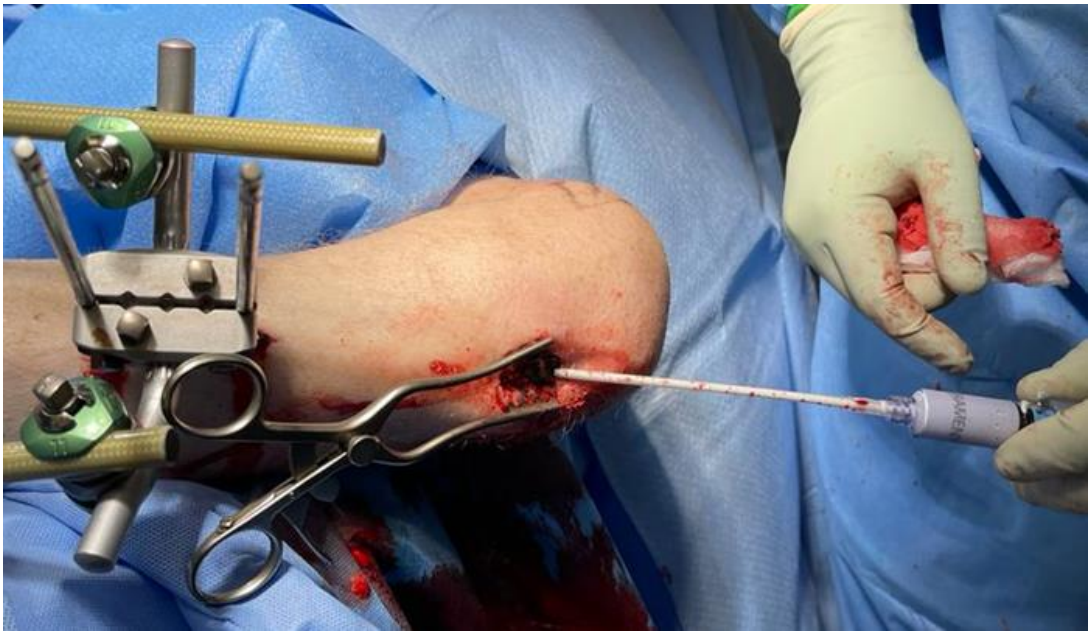

Figure 5: The remaining antibiotic carrier is injected inside the intramedullary nail with the fine filling catheter.

The limb is then kept still in order to achieve adequate conversion of the liquid ceramic to a solid state. Once this is complete (approximately 12-15 minutes), the nail is then locked using a standard drill to pass through the ceramic. Standard locking screws are used. The number and location of locking screws is based on surgeon preference.

Initial Clinical Experience

We have applied this technique in a series of 23 patients, including 11 with confirmed fracture-related infection and 12 with a high risk of infection after nailing (4 nails after external fixation, 4 nailing after previous osteomyelitis, 3 nails in suspected but unconfirmed infection and one nailing after a plate-assisted bone segment transport). There were 10 femurs, 9 tibias and 4 hindfoot fusion nails.

At a mean follow-up of 19.6 months (minimum one year), 21/23 (91.3%) were infection-free, with one recurrence in the confirmed infection group and one in the high-risk group. 18/21 (85.7%) were united. There were no complications related to the described technique. The antibiotic-coated locked nail allowed early, full weight-bearing in all patients, shortly after surgery.

Discussion

The use of intramedullary antibiotic carriers was originally described as the first part of a two-stage procedure. Infection was eradicated at the first stage using an antibiotic containing intramedullary rod (usually of PMMA), followed by subsequent exchange for an interlocked nail in order to provide stability and achieve union [16]. Good results were achieved with this technique however the requirement for a second procedure, often in an area with a suboptimal soft tissue envelope, presented a potential problem. This led to the development of techniques which allowed interlocked nails to be coated with PMMA containing antibiotic [17-24]. However, as described above, there are a number of potential issues with this method, both in terms of the coated nail itself and the use of PMMA as an antibiotic carrier. For this reason, it is optimal to use a bioabsorbable antibiotic carrier which will deliver local antibiotics over several weeks while also avoiding potential difficulties with the removal of debonded cement, in the event that further surgery is required.

A further indication for the use of these coated nails is in cases deemed at high risk of infection (nailing after external fixation, open fractures or active skin conditions) or in cases of non-union where a fracture-related infection is suspected but not confirmed [5,11]. In these cases, the definitive diagnosis of infection may not be available until after all microbiological and histological analysis is complete in the post-operative period. If results then confirm a non-union without infection, this technique allows surgeons to take comfort in the knowledge that the stability of the nail construct has not been affected, with no reduction in size required to allow for a cement mantel. If infection is confirmed, local antimicrobial therapy is already in place and no revision surgery is needed. Surgeons can treat these difficult cases, covering both infected and non-infected non-union, without compromising treatment.

We have chosen this ceramic material as it has been well investigated in infected cases. The material is licensed for this use (protection of implants from bacterial colonization) in Europe, the USA and widely around the world. It delivers very high levels of antibiotic locally with no concerns about systemic toxicity and with well-defined elution profiles [1,17,20-22]. It has also been associated with lower complication rates compared to other ceramic carriers and facilitates improved bone formation [2,7,8]. Potential issues with the use of the carrier include leakage of ceramic material from the wound. This has been reported when the carrier is used for management of osteomyelitis and fracture-related infection and affects 5-10% of patients [8,15]. Provided there are no other symptoms to suggest recurrence of infection, this wound leak can be managed conservatively and usually resolves completely within a short period. A further issue can occur if the carrier is agitated during the setting phase. Excessive movement can delay setting of the ceramic. The authors prefer to avoid any motion of the patient or the operative limb once the nail is *in-situ*, in order to prevent this occurring.

Previously, ceramic coating of intramedullary nails has been reported with application of the ceramic to the nail prior to insertion [10,25]. We do not recommend this as it is time consuming and the set, dry ceramic can separate from the implant during insertion. This will leave parts of the implant surface uncoated and exposed for bacterial colonization. It also removes a major benefit of our technique which allows ingress of the liquid antibiotic carrier into the surrounding medullary bone, pressurized by nail insertion.

Conclusion

In summary, this technique of coating Intramedullary Nails with a absorbable antibiotic carrier (INaac) is simple, combining readily available materials and standard fracture implants. Our early results are encouraging with a high rate of eradication of infection. We would expect further cases to unite with more time. Those who do not unite can be treated more easily without the problem of ongoing infection. With the advent of this new technology, allowing intramedullary nails to be loaded with high dose absorbable antibiotic carriers, the dogma of avoiding internal fixation in cases of confirmed or suspected infection can be re-examined.

Ethical Statement
Institutional review board approval was not required for the reporting of this surgical technique as no patient data was included. The patient figures were selected to protect the patient identity. Consent for use of surgical images was obtained from the patient.

Author Contributions
MMcN and JF conceived the idea and designed the surgical technique. EP and MMcN wrote the original draft. All authors contributed to editing of the paper and approved the final version.

Competing Interests
JF and MMcN report speakers' fees from Bonesupport AB outside of the submitted work. All the other authors declare no competing interests.

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Conflicts of Interests
The authors declare that there is no conflict of interest for this paper.

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