Research Article

Cost Comparison of Femoral Distraction Osteogenesis With External Lengthening Over a Nail Versus Internal Magnetic Lengthening Nail

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Abstract

Introduction: Femoral lengthening is performed by distraction osteogenesis via lengthening over a nail (LON) or by using a magnetic lengthening nail (MLN). MLN avoids the complications of external fixation while providing accurate and easily controlled lengthening. However, the increased cost of implants has led many to question whether MLN is cost-effective compared with LON.

Methods: A retrospective review was performed comparing consecutive femoral lengthenings using either LON (n = 19) or MLN (n = 39). The number of surgical procedures, time to union, and amount of lengthening were compared. Cost analysis was performed using both hospital and surgeon payments. Costs were adjusted for inflation using the Consumer Price Index.

Results: No difference was observed in the length of femoral distraction. Patients treated with MLN underwent fewer surgeries (3.1 versus 2.1; $P < 0.001$) and had a shorter time to union (136.7 versus 100.2 days; $P = 0.001$). Total costs were similar ($50,255 versus $44,449; $P = 0.482$), although surgeon fees were lower for MLN ($4,324 versus $2,769; $P < 0.001$).

Discussion: Although implants are more expensive for MLN than LON, this appears to be offset by fewer procedures. Overall, the two procedures had similar total costs, but MLN was associated with a decreased number of procedures and shorter time to union.

Level of Evidence: III

Lengthening of the femur has been performed by using distraction osteogenesis via the lengthening over a nail (LON) technique,[1] involving the use of a monorail external fixator to lengthen the femur over a femoral intramedullary nail. This technique results in much less time in the external fixator and fewer complications than the classic technique using the external fixator alone,[2,3] but many drawbacks remain, including the risk of pin tract infection, pin loosening, skin traction, regenerate fracture, regenerate deformity, premature or delayed consolidation, and knee and/or hip stiffness.[3-6] Although this technique results in successful outcomes for many patients,[1,7] motorized intramedullary devices have been developed with the goal of avoiding many of these complications.

Figure 1

Radiographs depicting treatment with LON and MLN. **A** through **C** depict LON: lengthening of the femur using an external fixator and intramedullary nail (**A**), consolidation of the regenerate after removal of the external fixator (**B**), and the ultimate removal of the intramedullary nail after union (**C**). **D** through **F** depict MLN: insertion of the MLN (**D**), consolidation of the regenerate after lengthening was completed (**E**), and the final result after removal of the nail (**F**). LON = lengthening over a nail, MLN = magnetic lengthening nail

The introduction of the magnetic lengthening nail (MLN) has gradually led some surgeons to shift their practices toward internal lengthening techniques.[8,9] Initial internal lengthening nail designs had many of their own complications, including difficulty controlling lengthening rate, mechanical device failure, premature consolidation, and insufficient bone regenerate.[10-14] Some studies even found that early devices had more complications than LON techniques.[7] However, as the implant design and function has improved over time, more recent studies of improved designs have shown that femoral lengthening via MLN may be performed reliably with excellent precision.[15-17]

Recent comparative clinical studies have shown that internal lengthening via MLN may reduce many of the complications associated with LON, such as pin tract infection, skin traction, knee stiffness, and regenerate fracture.[5,15,18-20] Furthermore, patients treated with MLN have been shown to have a shorter mean healing index, allowing earlier weight bearing, as well as improved patient satisfaction and perception of the cosmetic result of their surgery.[5] These studies have only reinforced patient and surgeon enthusiasm for the technique.

Although advances in the implant technology have led to improved patient outcomes with fewer complications, the high implant costs associated with MLN may exceed the clinical benefits. The purpose of this study was to determine whether there is a difference in the hospital, surgeon, and total cost between femoral osteogenesis via LON or MLN. Furthermore, combining clinical and cost data, we sought to analyze whether there is a difference in the relative cost-effectiveness of LON and MLN.

Methods

Patient Selection

All patients who underwent femoral lengthening via distraction osteogenesis at a single institution between 2005 and 2014 were included in the study. All surgical procedures were performed by the two senior authors of the study (S.R.R., A.T.F.). All patients had a minimum of 2-year follow-up. Because of a change in practice preference of the treating surgeons, patients in the earlier section of our period underwent LON (n = 19; 2005 to 2009), whereas those later in the period underwent MLN (n = 39; 2012 to 2014). LON was performed with an expectation of three procedures: osteotomy with the insertion of the intramedullary nail and application of the external fixation, removal of the external fixator, and eventual removal of the

Table 1

Demographic, Clinical, and Cost Comparison Between Patients Who Underwent Treatment With LON Versus MLN

Parameters	LON	MLN	*P* Value
Number	19	39	—
Female	10.5%	23.1%	0.260
Age (yr)	32.4 ± 14.6	29.2 ± 13.4	0.412
Length distracted (mm)	41.4 ± 23.2	38.5 ± 16.7	0.595
Time to union (d, total)	136.7 ± 50.4	100.2 ± 29.7	0.001[a]
Time to union (d, postdistraction)	85.6 ± 42.8	57.9 ± 31.7	0.008[a]
Total procedures	3.1 ± 0.8	2.1 ± 0.5	<0.001[a]
Inpatient procedures	1.9 ± 1.0	1.3 ± 0.4	0.002[a]
Outpatient procedures	1.2 ± 0.5	0.8 ± 0.5	0.005[a]
Outpatient office visits	9.3 ± 5.8	6.3 ± 3.1	0.021[a]
Total hospital costs ($)	45,913 ± 35,094	41,680 ± 22,345	0.875
Total surgeon costs ($)	4,342 ± 830	2,769 ± 768	<0.001[a]
Total cost (hospital + surgeon, $)	50,255 ± 35,103	44,449 ± 22,358	0.482

LON = lengthening over a nail, MLN = magnetic lengthening nail
[a] Signifies $P < 0.05$.

intramedullary nail. MLN was performed using the PRECICE nail (NuVasive) with an expectation of two surgical procedures: osteotomy with insertion of the MLN and removal of the MLN. The typical treatment protocols, as demonstrated by serial radiographs, may be seen in Figure 1.

Outcomes

Patient clinical records were retrospectively reviewed, including demographics, the number of inpatient and outpatient surgical procedures performed, total distraction length, and time to bony union. Bony union was determined based on continuity of three of four cortices on AP and lateral radiographs as well as the ability to fully weight bear without assistance or discomfort.

Cost analysis was performed from the payer perspective. We compiled the total payments received by the hospital for all care related to femoral lengthening, including surgical, inpatient, and outpatient visits. This total was included as the total hospital cost paid by the payer. For each surgical procedure performed, the Current Procedural Terminology (CPT) codes billed were recorded and used to calculate an expected surgeon fee using the Medicare Physician Fee Schedule (https://www.cms.gov/apps/physician-fee-schedule/), represented as the surgeon cost. A list of the included CPT codes can be found in Appendix 1. These two components were summed to calculate the total cost. To allow dollar values to be accurately compared over the study period, costs were inflation adjusted to be recorded in 2015 dollars using the chained Consumer Price Index (https://data.bls.gov/pdq/SurveyOutputServlet).

Statistical Analysis

Clinical and cost data were compared between the LON and MLN groups, using chi-squared tests for categorical data and *t*-tests for continuous data. Analyses were performed using STATA (version 14.2; StataCorp).

Results

Demographics

A total of 58 patients were included in the study, 19 of which had undergone LON and 39 who had undergone MLN (Table 1). Most patients were male, with an average age in the fourth decade. No notable difference was observed in demographics between the MLN and LON cohorts.

Clinical Results

The total length distracted was similar between groups (LON, 41.4 versus MLN, 38.5 mm; $P = 0.595$). The patients treated with MLN had a shorter overall total time to union (136.7 versus 100.2 days; $P = 0.001$). In addition, the time from distraction completion to final union was shorter for patients treated with MLN (85.6 versus 57.9 days; $P = 0.008$). The patients treated with MLN underwent on average one fewer surgical procedure (3.1 versus 2.1; $P < 0.001$), which resulted from both fewer inpatient and outpatient procedures (Figure 2).

Costs

The total hospital costs paid were similar between the groups ($45,913 versus $41,680; $P = 0.875$). Surgeon payments were markedly lower for patients treated with MLN ($4,324 versus $2,769; $P < 0.001$). No notable difference was observed in the total payments between the two groups ($50,255 versus $44,449; $P = 0.482$). A comparison of costs is shown in Figure 3.

Discussion

In this retrospective comparison of patients undergoing femoral distraction osteogenesis via LON or MLN techniques, treatment with MLN resulted in lower surgeon costs with no difference in total or hospital costs. Furthermore, the MLN technique resulted in a faster

time to final bony union with fewer surgical procedures.

In addition to similar, if not lower, cost of treatment, our data show that treatment with MLN may provide a better clinical experience for the patient. As has been described in past studies, MLN has many advantages over LON, including avoiding the use of external fixators. External fixators have many disadvantages, such as increased pain, skin traction due to pin travel, increased hip and knee stiffness, risk of pin-site infections, and social stigma.[3-6] Furthermore, despite a similar amount of lengthening between the cohorts, our data show that MLN leads to a faster time to union, thus allowing a shorter total treatment time and faster return to weight bearing and activity. These findings echo those of Laubscher et al,[5] who found similarly faster time to union for MLN compared to a monorail external fixator system. Furthermore, our data show that patients treated with MLN underwent on average one fewer surgical procedure, thus lowering the number of anesthesia episodes and risks associated therein. This discrepancy in the number of surgical procedures is inherent in the treatment protocols followed for each form of lengthening, as patients undergoing LON were expected to undergo three procedures compared with two procedures for MLN, and was not a result of an increased number of complication-related procedures.

The hospital cost data used in this study were a sum of all payments made to the hospital by the payer, which is a more accurate assessment of cost than total billings, as it reflects what the patient or insurance company actually paid for the treatment received, and thus the direct cost to the healthcare system. The surgeon billing data were calculated based on the Medicare Physician Fee Schedule in an attempt to standardize surgeon fees, as these may vary based on a patient's insurance plan and the reimbursement schedules for each patient's corresponding insurance plan were not available for use in this study.

Costs of prolonged treatment with LON exist that we were not able to measure but are important to consider. Patients undergoing LON required additional procedures and prolonged consolidation time compared with those undergoing MLN, which likely resulted in additional time away from work or other activities. Although not accounted for in this study, nevertheless, these indirect costs increase the treatment cost to society.

Figure 2

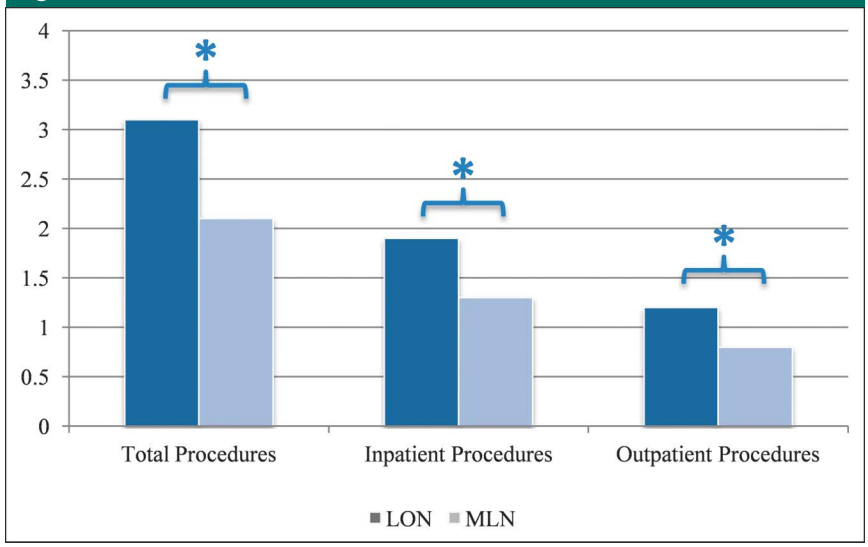

Chart showing the comparison of the number of procedures performed for patients treated with LON versus MLN. *Signifies $P < 0.05$. LON = lengthening over a nail, MLN = magnetic lengthening nail

Figure 3

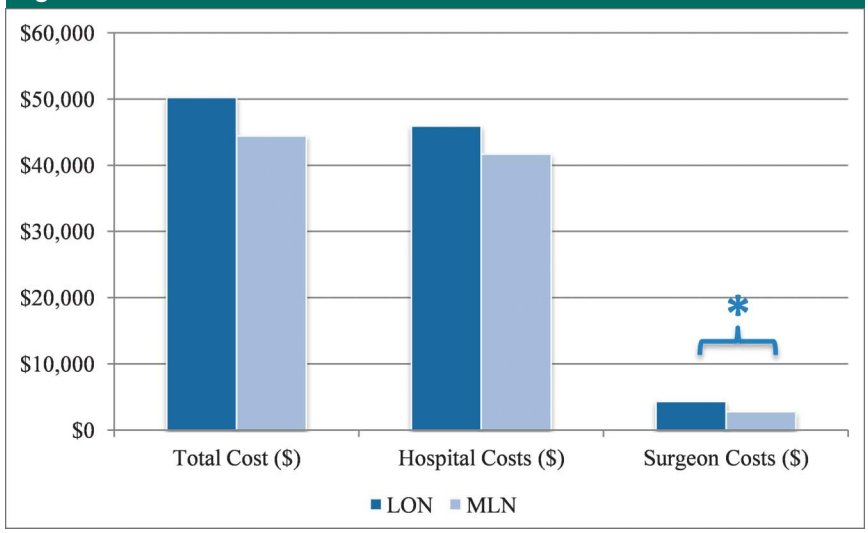

Chart showing the comparison of the total, hospital, and surgeon costs for patients treated with LON versus MLN. *Signifies $P < 0.05$. LON = lengthening over a nail, MLN = magnetic lengthening nail

This study does have limitations. The exact cost of various components of the treatment, such as the cost of the individual implants, was not available. The price paid for implants varies from institution to institution, and our institution could be paying less than others for the MLN implant. However, the idea that the price would be low enough to offset the measured difference in total cost is unlikely.

Furthermore, we were only able to measure direct costs paid by the payer; indirect or opportunity costs are not captured in our study. The surgeon cost was calculated based on the reimbursement rates provided by Medicare for the billed CPT codes and thus may differ from and not be applicable to patients with private payer insurance. Additionally, inherent bias may be observed between the two groups as they underwent treatment at different periods and with variable lengths of follow-up.

Conclusions

The results of this study indicate that similar distraction can be achieved with the MLN technique compared with the LON technique, but with few surgical procedures and with a faster time to final bony union. Despite the increased cost of implants for the MLN technique, the total payments were similar between the two groups, likely from the additional procedures and hospital care required in the LON technique.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 11 is a level II study. References 3, 5, 7, and 18 are level III studies. References 1-2, 4, 6, 8-10, 12-16, 20 are level IV studies. References 17 and 19 are level V expert opinion.

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Appendix 1

A Listing of the CPT Codes Used in the Calculation of Surgeon Fees.

Techniques	Encounter	CPT Code	Patients	Description
MLN	Surgery #1	27466	39	Osteoplasty, femur; lengthening
	—	27495	39	Prophylactic treatment (nailing, pinning, plating, or wiring) with or without methyl methacrylate, femur
	Surgery #2	20680	33	Removal of implant; deep (eg, buried wire, pin, screw, metal band, nail, rod or plate)
	Other codes	11044	1	Débridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less
	—	20902	1	Bone graft, any donor area; major or large
	—	27005	1	Tenotomy, hip flexor(s), open (separate procedure)
	—	27062	1	Excision; trochanteric bursa or calcification
	—	27305	4	Fasciotomy, iliotibial (tenotomy), open
	—	27334	1	Arthrotomy, with synovectomy, knee; anterior OR posterior
	—	27360	1	Partial excision (craterization, saucerization, or diaphysectomy) bone, femur, proximal tibia and/or fibula (eg, osteomyelitis or bone abscess)
	—	27430	1	Quadricepsplasty (eg, Bennett or Thompson type)
	—	27450	3	Osteotomy, femur, shaft or supracondylar; with fixation
	—	27470	1	Repair, nonunion or malunion, femur, distal to head and neck; without graft (eg, compression technique)
	—	27570	1	Manipulation of knee joint under general anesthesia (includes application of traction or other fixation devices)
	—	27687	1	Gastrocnemius recession (eg, Strayer procedure)
LON	Surgery #1	27466	19	Osteoplasty, femur; lengthening
	—	20692	19	Application of a multiplane (pins or wires in more than 1 plane), unilateral, external fixation system (eg, Ilizarov, Monticelli type)
	Surgery #2	27495	18	Prophylactic treatment (nailing, pinning, plating, or wiring) with or without methyl methacrylate, femur
	—	20694	18	Removal, under anesthesia, of external fixation system
	Surgery #3	20680	16	Removal of implant; deep (eg, buried wire, pin, screw, metal band, nail, rod or plate)
	Other codes	11044	1	Débridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less
	—	14020	2	Adjacent tissue transfer or rearrangement, scalp, arms and/or legs; defect 10 sq cm or less
	—	14021	1	Adjacent tissue transfer or rearrangement, scalp, arms and/or legs; defect 10.1 sq cm to 30.0 sq cm
	—	20693	1	Adjustment or revision of external fixation system requiring anesthesia (eg, new pin[s] or wire[s] and/or new ring[s] or bar[s])
	—	20902	9	Bone graft, any donor area; major or large
	—	27005	1	Tenotomy, hip flexor(s), open (separate procedure)
	—	27334	1	Arthrotomy, with synovectomy, knee; anterior OR posterior

(*continued*)

CPT = Current Procedural Terminology, LON = lengthening over a nail, MLN = magnetic lengthening nail
The typical codes used at each planned surgery throughout the two treatment protocols are delineated, followed by a listing of other codes included in the study.

Appendix 1 (*continued*)

A Listing of the CPT Codes Used in the Calculation of Surgeon Fees.

Techniques	Encounter	CPT Code	Patients	Description
	—	27430	2	Quadricepsplasty (eg, Bennett or Thompson type)
	—	27472	5	Repair, nonunion or malunion, femur, distal to head and neck; with iliac or other autogenous bone graft (includes obtaining graft)
	—	27479	1	Arrest, epiphyseal, any method (eg, epiphysiodesis); combined distal femur, proximal tibia and fibula
	—	38220	1	Bone marrow; aspiration only

CPT = Current Procedural Terminology, LON = lengthening over a nail, MLN = magnetic lengthening nail
The typical codes used at each planned surgery throughout the two treatment protocols are delineated, followed by a listing of other codes included in the study.