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Gamma nail in the treatment of closed trochanteric fractures.
Results and indications of 121 cases

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A R T I C L E   I N F O

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A B S T R A C T

The Gamma Nail is the latest advance in the treatment of trochanteric fractures based on intramedullary nailing principles during closed procedures. Its design is based on Küntscher’s Y-nail and locking intramedullary (IM) nails. This paper reports the results from the first-ever series of 121 patients operated between 1988 and 1990. They were followed until bone union was achieved. The mean patient age was 75 years. Most patients were in poor general health and had uveal fractures. Anatomical preoperative reduction was achieved in 72% of cases. Fixation was good in 66% of cases and acceptable in 27% of cases. Intra-operative complications consisted of nine fractures without consequences. Of the treated patients, 83.4% resumed weight-bearing during the first week. There was one case of deep infection that resolved with treatment. The mortality rate was 12.3% at three months. We noted 7 alunions in varus, 3 in valgus, 2 in external rotation and 1 in internal rotation. There were no cases of non-union. In six cases, the screw had cut out of the femoral head. The drawbacks associated with surgical treatment methods for trochanteric fractures also apply to the Gamma nail. Nevertheless, one of its primary advantages is the possibility of using a closed procedure. When compared to Ender nailing, knee pain is absent and weight-bearing can be achieved in all patients, no matter the fracture type.

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1. Introduction

Trochanteric fractures are problematic in the Western world because of the wide-ranging human social and economic repercussions. Because the frequency of these fractures increases with age, these effects will only get worse as our population ages. The number of trochanteric fractures is expected to double between 1980 and 2000 [15].

Fracture treatment aims to allow patients to quickly resume weight-bearing so as to improve survival. Progress has been made in achieving this goal with both open (slide plate and screw plate) and closed (modified Ender nailing) treatment methods. Preventative measures have been implemented in parallel that should have a positive impact over time: balanced calcium-phosphate intake, calcium and vitamin D administration, and oestrogen administration in women. But further research needs to be performed to improve current internal fixation methods. The Gamma nail is the newest implant designed to treat these trochanteric fractures using a closed intramedullary (IM) fixation method.

The method is similar to the procedures designed by Küntscher [10], who proposed a fixation device that was introduced either through the trochanter (such as the Y nail; the Gamma is a direct descendant) or further away through the distal metaphysis (trochanteric nail design adopted by Ender and to a lesser extent, Letzius and Simon-Weidner [2]). Ender nailing [2,6] was rapidly adopted in the 1970s, but limitations quickly appeared: 25–30% subsidence which induced knee pain and required surgical revision in 20% of patients; high number of malunions in external rotation and varus, implant cut out at the femoral neck, bone flaking and fracture at the introduction point, etc.

The sliding screw fixation mechanism proposed by Kempf and Bitar [7,8] to prevent nail subsidence and re-operations, greatly reduced the number and severity of malunions and implant cut out at the femoral neck. But it was still inadequate in several aspects:

- chronic knee pain and discomfort;
- construct not reliable enough to allow early weight-bearing in patients with more complex fractures. Type 6 intertrochanteric and type 7 subtrochanteric were borderline indications; type 8 trochanter-diaphysis junction was either contraindicated or required 4-6 weeks of continuous extension;
- the method was difficult to perform in young people because of the density of cancellous bone in cervicotrochanteric fractures and fractures in a coxa vara hip.

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2. Materials and methods

Implant and surgical technique

These reasons led us to develop a new fixation method that still used closed procedure and locking IM nail principles [3]. We were inspired by Küntscher Y nail (Fig. 1) because of its sound mechanical basis. However, the insertion technique for the Y nail is painstaking and the construct is quite basic, with the thin intramedullary nail having a tendency to slide up or down.

The idea came to us to invert the mechanical configuration of the Y-nail while maintaining its basic principles.

The Gamma nail (Fig. 2) consists of a large intramedullary locked nail with a valgus curvature, an upper part shaped as a funnel, a large proximal opening to allow insertion of a long femoral neck screw and two small horizontal holes to allow for distal locking. The femoral neck screw can slide within the nail. We believe this feature is quite important as it allows the construct to “follow” the fracture site settling and avoid neck cut out.

Although femoral neck screws are available in various diameters, lengths and angles, the standard nail is 20 cm long. Longer Gamma nails are available for certain types of subtrochanteric fractures and fractures with diaphyseal extension (Fig. 3). The provided instrumentation allows the various surgical steps to be performed reliably.

Our surgical technique has previously been described in great detail [9]. The main steps are summarized below:

- reduction on the traction table must be as perfect as possible before starting the procedure; planning is performed using X-rays of the reduced fracture to determine the appropriate nail length, diameter, angle and anteversion. The insertion point for the alignment jig and nail must be at the top of the greater trochanter;
- the femoral canal is reamed up to 2 mm more than the nail diameter, which allows the nail to be inserted manually without a hammer;
- the neck screw must be inserted from the bottom and advanced until it contacts the medial cortex of the femoral neck on an A/P view and is in the middle of the neck on the lateral view. The screw will extend up to 1 mm from the joint space (Fig. 4).

No additional support is needed. The patient can easily be placed in a wheelchair without experiencing knee pain. No matter the fracture type, the patient is allowed to stand early on without restrictions on weight-bearing, using two canes, a frame or a third person.

Study description

From March 30, 1988 to November 29, 1990, 236 nails were implanted. The results from 121 patients were available for analysis. The inclusion criteria consisted of at least three months follow-up with full clinical and radiological outcomes.

At first sight, this follow-up period does not seem long enough. However, we were limited because these elderly fracture patients could not be followed for a long time. Most do not return to see us once the fracture has healed, which occurs around the end of the third month. It also became increasingly difficult to monitor a patient’s condition during a longer follow-up because the healthcare system no longer covered the expenses of driving patients to our facility. This confluence of reasons resulted in many patient files not being usable. Despite these challenges, the studied population was representative all the operated patients in terms of age and fracture type. There were 88 women and 33 men. The women had an average age of 78 years and the men, 66 years. Patients ranged in age from 21 to 99 years.

The patients were often in poor general health. Based on the Singh Index for Osteoporosis [14], there were 31 patients at Grade VI (no osteoporosis), 48 at Grade V & IV, 33 at Grade III & II, and 9 at Grade I (severe osteoporosis). Based on the 5-point ASA physical status classification system, 6 patients were Class 1, 13 were Class 2, 61 were Class 3, 35 were Class 4 and 7 were Class 5. Functional pre-operative assessments revealed that 23% needed one or two canes to ambulate, and that 45% had a limited walking distance.

Fracture characteristics

The right femur was fractured in 51 cases and the left one in 70 cases. All were due to trauma, mainly following an insignificant fall. These consisted of 15 cases of severe trauma, 3 pathological fractures, 3 revisions of other fixation techniques and one revision for non-union secondary to Ender nailing.

Based on the Ender (Fig. 5a) and Evans (Fig. 5b) fracture classification systems, most fractures were unstable. To treat stable fractures (mainly type 1, sometimes type 4) we still perform Ender nailing [2,6].

Surgical procedure
An average of 27 hours (range 4 to 120 hours) had elapsed between the accident and procedure, and 20 hours (range 7 to 96 hours) between the admission and procedure. Only a particularly fragile medical condition would delay the procedure; the most opportune time for surgery was the day after admission. As a consequence, trochanteric fractures can be considered a deferred emergency surgery.

3. Results

A Intra-operative

1 - Procedure duration

The average total operating time (from initial incision to final closure) was 41 minutes (range 10 to 140). In 96 cases, the procedure was performed under spinal anaesthesia and in 25 cases under general anaesthesia. Average anaesthesia times could only be reliably measured in patients who underwent general anaesthesia. In these patients, it was 130 minutes (range 70 to 240) from intubation to extubation. The true duration of the procedure was longer because of preparation, placement on table, reduction, fluoroscopy verification, planning, postoperative X-ray verification and return to the ward.

2 - Reduction

Reduction quality was determined on the X-rays used for surgical planning. The neck-shaft angle, neck anteversion on lateral views and maximum diastasis at the main fracture line on A/P and lateral views were taken into consideration. Irradiation during fluoroscopy was only 84 seconds on average.

The reduction was deemed anatomical if the neck-shaft angle and anteversion were the same as the uninjured side and the maximum fracture diastasis was no more than 5 mm (including X-ray magnification). Based on these criteria, anatomical reduction was achieved in 88 cases (72%). An acceptable reduction was defined as one with less than 5° alignment defect on A/P views and 10° for anteversion, with less than 10 mm fracture diastasis. This was found in 25 cases (20%). The other 8 cases (1.7%) were qualified as poor.

3 - Implants

A 12 mm diameter, 130° nail with a 100 mm femoral neck screw was used in most cases. The device was locked in 104 cases; every unstable fracture (with medial comminution) had to be locked.

4 - Fixation quality

Various parameters were evaluated. The nail entry point was considered ideal 86 times, too medial 7 times, too lateral 19 times, too posterior 7 times; the nail was never placed too anterior.
Fracture diastasis was measured on the main fracture line on postoperative X-rays. It was 4.7 mm on average on A/P views (greater than 10 mm eleven times) and 5.0 mm on average on lateral views (greater than 10 mm sixteen times). The gap between the apex of the screw and the medial femoral cortex on A/P views was 10.4 mm on average (range 2 to 27 mm). The femoral neck screw extended beyond the lateral edge by an average of 14.6 mm (range 3 to 28 mm). The screw fixation was deemed good in 86 cases and poor in 10 cases.

In 6 cases (4.9%), the initial fracture reduction was altered when the nail was inserted: once leading to valgus alignment, once leading to varus alignment and four times causing distraction, but in the latter cases contact was re-established upon loading.

The position of the femoral neck screw within the femoral head (Fig. 6) was compared to the optimal position (inferior on A/P view and centred on lateral view) to provide support to primary compression trabeculae. Overall, 80 constructs were described as good (66%), 33 as acceptable (27%) and 8 as poor (6.6%).

5 - Intra-operative complications

The proximal metaphysis split in nine cases (7.4%) during nail insertion. This occurred either in a new location or as an extension of a pre-existing crack (Fig. 7). None of these incidents affected patient function or delayed weight-bearing.

There were six problems during the locking step. Two constructs could not be locked (broken drill bit and wrong alignment of both screws). In one case, locking resulted in misplacement of the screw, which led to an intra-operative femoral shaft fracture that was fixed with a plate and subsequently healed. In the three other cases, the locking step could not be carried out because of poor aiming.

These splits, cracks and metaphysis-diaphysis junction fractures are a true danger for the patient. They can be avoided by over-reaming and manually inserting the nail, without using a hammer. The amount of muscle in that location also makes it difficult to lock the nail.

B - Postoperative outcomes

1 - Blood loss

The postoperative blood loss was determined by the volume collected in the suction drains. The average was 166 cc (range 10 to

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<th>Position</th>
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<th>Middle</th>
<th>Inferior</th>
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<td>33</td>
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<td>posterior</td>
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Fig. 6. Position of neck screw in the femoral head.
700 cc). Blood transfusion was required during or after the surgery in 44 patients (36.3%), with an average of two units given. Thus, use of the Gamma Nail was moderately haemorrhagic.

2 - Time before weight-bearing

Early full weight-bearing was defined as standing and loading during walking with the help of two canes and/or another person or a frame, and without restrictions being placed on loading the affected leg. Under these conditions, 83.4% of patients resumed weight-bearing during the first week, independent of fracture type.

3 - Early postoperative complications

a - Local

There were six cases of haematoma, but only one had to be surgically drained. There were three superficial infections (one leading to partial wound dehiscence) but none required surgical revision; every case resolved with bandages and second-intention healing. One deep infection required Gentallin bead implantation, but no hardware removal.

b - General

Eight patients died within 15 days of the procedure. There were 11 lung-related complications that were typically serious, with seven being the cause of death. There were three cases of confirmed phlebitis; 86.7% of patients underwent venous thromboembolism prophylaxis and there were no cases of pulmonary embolism.

4 - Hospital discharge

The patient’s destination upon discharge from our hospital partially revealed their functional capacities: 49% were able to return home, 24% were transferred to an old-age home, 24% to a rehabilitation facility and 3% to a secondary hospital.

C - Three-month results

1 - Time to bone union

Bone union occurred in 2.7 months on average, which is similar to other methods. Union took more than three months in 11 patients, mainly those with complex trochanter-diaphysis junction fractures. One patient had a non-union, but this was a unique case: revision of non-union following Ender nailing that was not resolved by Gamma nailing; the patient underwent subsequent hip arthroplasty.

2 - General complications

Including the early deaths mentioned earlier, there were 15 deaths within three months (12.3%). At the time of follow-up, three patients were bed-ridden.

3 - Local complications

a - Hardware-related

There were no hardware failures, nail breakage or buckling or breakage of the locking screws. The locking screws moved back up to the skin in one patient. These screws were too short to

Fig. 7. a: Ender type 2 pertrochanteric fracture; b: X-rays taken after reduction; c: additional fracture after nailing that is well controlled by the Gamma nail.
provide good fixation in a very osteoporotic medial cortex; they were replaced by expanding screws.

b - Secondary displacement
Seven fractures had healed with secondary displacement of more than 10° varus (5.7%) and three in more than 10° varus, but these were all reduced into valgus. Two special cases were observed: union with femoral head rotation (fracture at neck base) and union with femur medialisation due to the femoral neck screw backing out excessively. There were also two cases of union in external rotation greater than 10° and one case in internal rotation greater than 10°.

There were six cases of implant cut out in the femoral neck (4.9%). These mostly occurred two months after the surgery. In two cases, the femoral neck screw was obviously too short and in four cases it was badly positioned in the head. The worst possible screw position would be in the upper quadrant on A/P view and posterior quadrant on lateral view (Fig. 8).

c - Avascular necrosis. There were no cases of femoral head avascular necrosis, but the follow-up was not truly long enough to detect this complication.

4 - Functional result at three months
Functional results were evaluated based on the types of walking aids used. At the time of follow-up, 49% of patients were living at home. Of these patients, 33 patients (27.2%) walked without canes, 27 patients (22.3%) used one cane, 31 patients (25.6%) used two canes, six patients (4.9%) used a frame and four patients (3.3%) no longer walked, thus were confined to a bed or wheelchair. Three of the patients who were initially bed-ridden died before the end of the third month.

4. Discussion
Because most published retrospective studies were performed at different facilities, used different implants and had different
outcome measures, comparing them is difficult. There are no prospective, randomized studies available that can be used to objectively evaluate the advantages and disadvantages of these various treatment methods. Nevertheless, we compared our new method with the two methods that are or have been used the most: sliding hip screw with lateral plating (DHS and THS) and Ender nailing with sliding screw fixation, which we also use.

The total operating time was 77 minutes with the DHS [13], 55 minutes with locked Ender nails [4,5,12] and 45 minutes with the THS [11]. It was 41 minutes for the Gamma nail, evidence of the advantage of closed procedures. Nevertheless, given the advances in anaesthesia, the speed of the procedure is no longer a determining factor, even though such advances are better for the patient.

Blood loss was harder to evaluate because few series report it. One prospective, randomized study found less blood loss with the Ender procedure than the DHS one [1]. There was significantly less blood loss in patients receiving a Gamma nail (148 mL) relative to the DHS (522 mL) and fewer units transfused (0.95 vs. 1.82) in Penot’s retrospective study [13]. Müller [12] reported that 78% of Ender nail fixation cases did not require transfusion. In our series, 35% of patients received a transfusion for the same amount of blood that was lost through the suction drains (219 cc). Non-transfused patients lost 114 cc, with the average loss being 166 cc. Close fixation methods resulted in noticeably less blood loss.

The quality of preoperative or intra-operative reduction was deemed perfect or nearly perfect in 78% of cases with the DHS [13], anatomical or intentional slight valgus in 88% of Ender cases [12], anatomical in 72% of the Gamma nail cases reported here, along with being acceptable in 20% of cases. We will readily admit that precise fracture reduction requires an open procedure. But this assertion is contradicted by all those who reduce fractures on the table and know that it is fully possible to achieve a reduction that is anatomical or in the very least, mostly acceptable.

Our data confirm that reduction quality is similar with closed and open techniques. But a few fracture types are problematic:

- complex pertrochanteric fractures (Ender type 2) with detached lesser trochanter; however, we believe this fragment does not need to be replaced accurately as it will heal even if greatly positioned to the inside;
- some type 7 fractures or more often type 8 trochanter-diaphysis junction fractures; we have encountered two different scenarios.

1) Oblique fractures below and behind on lateral views (Fig. 9, arrow); even with significant displacements we have always been able to obtain excellent closed reduction.

2) Oblique fractures below and in front, often shorter than the previous ones, with flexion-abduction displacement of the proximal fragment and posterior drop of the distal fragment. This fracture type poses a true problem: reduction through external manoeuvres is incomplete or does not hold, despite using external bracing (Fig. 10) and the surgical result is open to criticism. These were acceptable to us in our early cases because the final result after bone union was generally satisfactory. But we now recommend open reduction to put the finishing touches on the reduction, without using additional fixation methods.

Fixation quality
In published studies with the DHS [12,13], 10% to 39% of implants were positioned incorrectly. In our series, 59.7% of implants were positioned perfectly (grazing the inferior cortex of the neck). This low value can be attributed to having placed the screw in the middle of the neck in our early cases. Seven of our 13 poorly-centred implants had mechanical complications. Given this result, we have to speak up against the widespread opinion that closed fracture fixation is easy, since gross reductions are tolerated. Closed procedures have requirements that go beyond those of open procedures, thereby demanding a strict, precise technique that cannot be improvised and requires training and experience.

Fracture fixation with the DHS was supplemented by additional screws, plates, cerclage wire, cancellous bone grafts or cement in 9% to 20% of cases [12,13]. These have never been needed with the two closed fixation methods. But we must emphasize that these are two different treatment concepts: advocates of open procedures aim to precisely reduce every displacement; supporter of closed procedures (and many French teams) do not try to achieve anatomical fixation in every case.
Fig. 10. a: Ender type 8 fracture at trochanter-diaphysis junction (lateral view) that is oblique inferior and anterior; challenging reduction even with posterior bracing; b: Gamma nail in place; c: final X-rays (no functional disturbance).

The time to full weight-bearing is difficult to compare because the number of unstable fractures must be taken into account in studies with sliding screw plates and Ender nails:

- with the DHS, Müller [12] reported that 36% of patients achieved full weight-bearing after the first week, although 63% of the 60 patients evaluated had stable fractures;
- in the Penot study [13], full weight-bearing was achieved after surgery in 76% of patients operated with a DHS (59% stable fractures) versus 85% for patients operated with a Gamma nail (69% stable fractures);
- most the patients (85%) operated with the THS [11] were able to bear weight before the tenth day. This compares to 90% with Ender nailing [12] by the end of the first week and 83.4% with the Gamma nail by the end of the first week. Note that our series included a greater number of unstable fractures (69%).

Here lies one of the indisputable strong points of this treatment method: the degree of fracture instability does not factor into the return to weight-bearing. This makes it better than other open and closed methods including Ender nailing, which already had one positive aspect in this area.

We found a clear difference in favour of closed procedures, as they had fewer superficial and deep infections. The infection rate was 2.4% for Gamma nailing and Ender nailing [12]. Note that our only deep infection healed without problems, whereas a trochanteric infection after open fixation is generally catastrophic. For DHS, the rate varies between 0.8 and 16.9% [1,5,13].
Table 1
Comparison of open and closed procedures used to manage trochanteric fractures.

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<th>Open procedure</th>
<th>Closed procedure</th>
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<tr>
<td>Reduction quality</td>
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<td>Good</td>
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<tr>
<td>Operative time</td>
<td>Longer</td>
<td>Shorter</td>
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<tr>
<td>Additional procedures</td>
<td>Sometimes</td>
<td>Never</td>
</tr>
<tr>
<td>Time to weight bearing</td>
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<tr>
<td>Infection</td>
<td>↑ risk</td>
<td>↓ risk</td>
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<tr>
<td>Secondary varus displacement</td>
<td>Low rate</td>
<td>Higher rate</td>
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<tr>
<td>Functional results</td>
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There also seemed to be fewer deaths when the Gamma nail was used: 12.3% in comparison to 15% with DHS [13], 20% with THS [11] and 20.4% with Ender nailing [12]. However, these data must be interpreted cautiously since the study duration was different between series.

The comparative, retrospective series by Penot [13] found no significant difference in the mechanical complication rate between the DHS and Gamma nail (6.2% vs. 8.9%). In 119 cases of Ender nailing, there were 10 cases with more than 10° varus (10%) and five cases of malunion with more than 10° external rotation (4.2%). In the current series with the Gamma nail, we found 14 cases of varus (11.5%) and two cases of malunion with more than 10° external rotation (4.2%).

These data lack precision because shortening is not included in these two methods, but it automatically produces varus displacement. Nevertheless, the data provide evidence of the secondary displacement and settling of certain types of trochanteric fractures that occur no matter which fixation method is used. This is taken into account in all three fixation methods, as there is a possibility of sliding along with settling.

The time to union and union rate were similar for all three methods, which confirms a widely known fact that trochanteric fractures have an excellent union potential.

Table 1 compares the advantages of open and closed techniques for the implants in question.

5. Conclusion

Fracture fixation using the Gamma nail technique is not without its problems, but it can be applied in nearly all cases without supplemental devices and without opening the fracture site. Its mechanical soundness allows for early weight-bearing in most cases. Although malunions are more common than with DHS fixation, their severity is acceptable as they have no major functional impact.

In theory, all types of trochanteric fractures can be treated with this method. In practice, some nuances must be highlighted:

- only unstable fractures can unquestionably be treated with this method;
- for stable simple pertrochanteric fractures (type 1 and some types 2 & 4), modified Ender nailing is the best indication as it is less costly.

The Gamma nail is indicated for:

- cervical-trochanteric fractures;
- fractures in coxa vara hips;
- pathological fractures;
- fractures in young patients, although the femoral neck screw is hard to insert;
- treatment of non-unions.

A longer implant could allow treatment of some combination fractures (neck and shaft or pertrochanteric and shaft) or trochanter-diaphysis junction fractures.

Disclosure of interest

Authors’ disclosure of conflict of interest was not requested when the article was originally published.

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