INTRAMEDULLARY NAILING

History

<1900 Hey groves	solid metal rods for femur fractures
1927 Rush	Multiple flexible intramedullary pins
1940 Küntscher	slotted cloverleaf nails.
1950 Herzog	introduced the tibia nail with a proximal bend and lateral slots at the distal [antirotational wires].
1960 Klemm, Kempf	precursors to today's interlocking nails.
1990's Sanders	Trochanteric nails

The major advantage is the biomechanical ideal position of the implant in the center of the bone. On the other hand, a major problem is how to control axial displacement or neutralize rotational forces. The interlocking techniques have helped to solve these drawbacks to a great extent.

For femur and tibia nailing is a gold standard treatment. For the humeral shaft, intramedullary nails are an option competing with the still very popular and more versatile plating techniques. Flexible nails as used in pediatric fractures have been advocated for the clavicle, while nailing of the forearm bones has not yet proved to be equal or superior for the **fixation** for ulna and radius fractures due to the difficulty of reliable locking systems that can control the rotational forces.

Mechanics of intramedullary nailing

küntscher's original concept was based on the principle of elastic deformation or "elastic locking" of the nail within the medullary canal. to increase the elasticity, the hollow cloverleaf nail was slotted, and reaming of the canal enlarged the area of contact and friction between the nail and the bone.

The weak point of the first nails remained the poor resistance to axial (telescoping) forces and rotation, especially in comminuted fractures. The introduction of interlocking screws and bolts at the proximal and distal end of the nail addressed these issues.

The clinical experience as to the infection rate in open fractures was most encouraging; however, the time to union took longer, especially in the majority of cases where the original concept of secondary exchange nailing to a thicker nail was not followed. The enthusiasm for the new nails without reaming resulted in a higher incidence of delayed and malunions due to a poorer mechanical stiffness of the construct.

Basic Science

Rhinelander: Inner 2/3 rd of the cortex is supplied by the nutrient vessel

Outer 1/3 by the Periosteal vessel

Normal circulation is centrifugal: predominant from center to periphery

During fracture healing is centripetal distribution

Animal study: * Reamed Nail: cortical revascularization in 12 weeks

Unreamed Nail: 6 weeks in sheep model.

* Reamed Nail: increased periosteal blood supply than unreamed.

* No difference in callus strength

Physiology of reaming

1. Damages the endosteal circulation
2. Enhances periosteal circulation
3. Overall blood supply is maintained
4. Extruded marrow: osteoinductive
5. Effect is not same in open fracture.
6. Equivalent effect in tibia and femur

Pathophysiology of intramedullary nailing local effects

1. Endosteal blood supply is reversible within 8 to 12 weeks. Earlier in unreamed than in reamed. Therefore theoretically unreamed in open fractures is preferred.
2. On the other hand, the bone debris produced during the reaming has been shown to act like an autogenous bone graft, enhancing fracture healing.

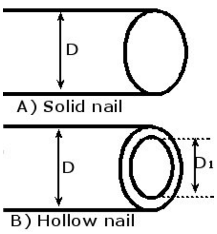
Systemic response

reaming has been associated with pulmonary embolization, coagulation disorders,

In clinical and experimental studies, the passage of large thrombi into pulmonary circulation has been demonstrated with intraoperative echocardiography especially during the reaming process. nevertheless, there is an ongoing controversy between the advocators of reamed nailing also in the multiply injured patient.

Bending stiffness

Wider nail stronger it is. Radius to the power 4: r^4



Solid Nail = D^4

Hollow nail = D^4 - D_1^4)

Bending moment of adult femur **– 250 nm**

Load the femur must sustain during walking **- 125nm**

Torsional rigidity

Torsional rigidity increases with the r4. Therefore if the radius of a nail is doubled the torsional rigidity increases by a factor of 16.

Working length

In a comminuted fracture: the length of a nail between the most proximal point of fixation in the distal fragment [A] and the most distal point of fixation in the proximal fragment [B].

The distance between A and B is the working distance. It is the unsupported portion of nail between the bone fragments.

Bending stiffness is inversely proportional to the square of the working length.

Torsional stiffness is inversely proportional to the working length

For a fracture located within 5 cm of the most proximal distal locking screw, the peak stress around the hole may exceed the endurance limit of the metal. The nail is loaded as a cantilever beam.

Nail diameter

Bending stiffness = radius to the power 4

slotted nail: 40 times decrease in **torsional stiffness**

Distribution of material:

A wider diameter hollow tube is stiffer than a solid smaller diameter tube with the same amount of material, and the outer fibre stress for a given bending moment is reduced.

This is defined by the second moment of area [a property which measures the distribution of the material around the cross section].

Tubes with a wall thickness: radius ratio of less than one eighth tends to behave as curved sheets rather than tubes. These thin-walled tubes are subject to buckling.

Property of the nail depends on

1. Size of the nail and strength
2. Reamed vs unreamed: in both medullary circulation is compromised.
3. Working length
4. Slotted or not
5. Solid or hollow
6. Titanium has modulus closer to the cortical bone.

Damage is caused by first reamer and subsequent has not importance.

Intramedullary pressure

Normal:	30-50 mmhg
IM reaming	800 mmHg
Noncemented prosthesis	800 mmhg
Cemented prosthesis	1400 mmHg

Reaming technique is improved

a. Increase in gap length: power 3
b. Decrease in the length of seal (short reamer with sharp, deep flutes)
c. Reaming with less compression force

These changes increase black flow and decreases importance of disadvantages claimed for reamed nailing.

Presently, nonunion is 7.5% in unreamed as opposed to 1.7% in reamed Nailing.
PE and embolism: not different [Tcherene and Papas]
High rate of implant failure with unreamed nail.

Planning for nailing

Antegrade or retrograde [No difference; problems with nail sizing and rotation control with retrograde]
Reamed or unreamed
Interlocking: single or double screw
Dynamise or not [no difference on healing].
'static or dynamic'
Fracture table or ordinary table
Image intensifier

Reaming and pulmonary complications

Pape	High incidence of PE after IM nailing
Charash	Opposite results; early fixation better
Wolinsky	Animal model failed to show this association
Christie.	Mild type of embolic shower but of no clinical significance
Bosse	Chest injury with plate or IM nail, no difference in ARDS
Wozasek	Maintaining blood perfusion, hypoxia, blood pressure is more important than reamed or not unreamed.
Rixen	Reaming is safe when ISS is less than 25 [J Trauma: 41:769]

Present trend: E**arly aggressive** treatment of shock [J Trauma 2000: 49:480]. Failure of which cause hypotension leading to inflammatory cascade: neutrophilia, release of superoxide, damages the capillary and may sensitize tissues to emboli from reaming [normally: these emboli are benign].

All fractures: static fixation

Number of distal screws: single or double.
double is preferred : early weight bearing mobilisation.
if nwb = single is adequate