

TECHNICAL ASPECT OF BONE
GRAFT HARVEST WITH BIOLOGY OF
FUSION IN SPINE SURGERY
(AUTOGRAFT, ALLOGRAFT AND
RECENT ADVANCES)

3 sections

- *Biology of fusion in spine*
- *Autograft allograft and recent advances*
- *Technical aspects of bone graft harvest and complications*

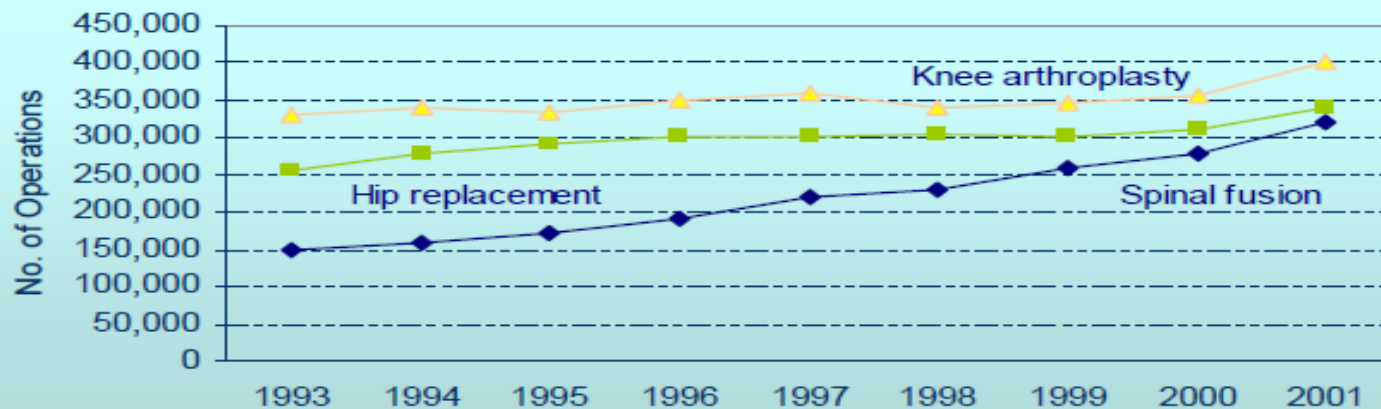
BIOLOGY OF SPINAL FUSION

- Spinal fusion

1911 Albee (Pott disease)

Hibbs (scoliosis)

Now treating more “discogenic back pain”



- **GRAFT INCORPORATION**

- Depends on material, implant site, disease state.
 - Following Implantation
- 1. Hematoma
- 2. Inflammation/MSC
- 3. Blood vessel invasion
- 4. Bone formation at graft surface

- Inflammation stage - release of growth factors
- Collagen formation simultaneous with collagen degradation
- Mechanical Environment
- Tissue Quality...e.g. scar tissue, heart disease, immunocompromised, smokers , steroids

Smoking

- Decrease in trabecular bone volume and fusion mass
- Decrease osteoblast differentiation
- Calcitonin resistance
- Impaired vascularization
- Increase platelet aggregation and vasoconstriction

Spinal fusion

- Three biological mechanism are involved:
 - **Osteogenesis:**
 - production of new bone by proliferation, osteoid production and mineralization
 - **Osteoconduction:**
 - production of new bone and migration of local osteocompetent cells along a conduit e.g. fibrin, blood vessel or even certain alloplast material like hydroxyapatite
 - Originate from the endosteum or residual periosteum of the host bone
 - **Osteoinduction:**
 - formation of bone by stem cells transforming into osteocompetent cells by BMP
 - It induct the recipient tissue cells to form periosteum and endosteum

Spinal fusion

- The basis of spinal fusion is **bone formation**
 - in an *osteoconductive environment*
 - by *osteoprogenitor cells*
 - induced by *osteoinductive agents*
- The success of spinal fusion also depends on
 - *anatomical location*
 - *biomechanical environment*
 - *surgical approach*
 - *internal fixation*

Bone Formation Requires

- *COMBINATION of:*
 - **Vascularity**
 - **Stability**
 - **Progenitor cells**
 - **Structural matrix**
 - **Growth factors**

NET BIOLOGIC ACTIVITY

- *SUM of:*
 - **Inherent biologic activity**
 - **Living cells and products**
 - **Osteoinduction capacity**
 - **Osteoconduction capacity**
 - **Capacity of the surrounding tissues to **activate** the process**

Alterations in Healing

- *DEFICIENCIES of:*
 - **Vascularity**
 - **Stability**
 - **Progenitor cells**
 - **Structural matrix**
 - **Growth factors**

Autograft , allograft and recent advances

- **WHAT IS A BONE GRAFT**

Word 'graft' conjures image of transplant tissue, not true but is the terminology used.

Any implanted material that alone or in combination promotes a healing response by osteogenic, osteoconductive or osteoinductive activity....

Literature Review – Levels of Evidence

- *Vast number of :*
 - Dental 46%
 - Basic Science/Animal 25%
 - Spine 11%
 - Small series 5%
 - Review articles 14%

*ALL GRAFT MATERIAL is DEPENDENT
on the LOCAL and SYSTEMIC
ENVIRONMENT*

Without a good host and host bed
ANY material WILL FAIL!

Host factors

Obesity
Smoking

What to Use? - 125+ Choices!

- The graft must supply that which the host lacks.....
- The host must supply that which is not inherent to the graft!!

Ideal Bone Graft Substitute

- Biocompatible
- Bioresorbable
- Osteoconductive
- Osteoinductive
- Easy to use
- Cost effective

Choices of Graft Material

- Autograft
- Growth Factors
- Allograft
- Biosynthetic
- Composite
- Future?

AUTOGENOUS BONE GRAFT

- *GOLD STANDARD*
- **Osteoconductive**
 - Hydroxyapatite , Collagen
- **Osteoinductive**
 - BMP, TGF-B
- **Osteogenic**
 - Osteoprogenitor cells

Autogenous bone graft

- *Ideal Bone Graft Substitute*

- ***Biocompatible***
- ***Bioresorbable***
- ***Osteoconductive***
- ***Osteoinductive***
- ***Easy to use***
- ***Cost effective***

- *ADVANTAGES*

- ***Histocompatible***
- ***No risk of transmissible disease***
- ***Osteogenic cells and proteins***
- ***Rapid incorporation***
- ***Structural, workable***

AUTOGENOUS BONE GRAFT

LIMITATIONS

- Limited Quantity
- Limited Structure and shape
- Variable osteogenic potential
- **DONOR SITE MORBIDITY- 2-35%!**

Bone marrow aspirate

- Autogenous bone marrow aspirated from iliac crest or vertebral bodies - potentially osteogenic cells
- Pluripotential stem cells- differentiation along osteoblast lineage
- Initial 2 ml = 2400 alkaline phosphatase-positive colony forming units
- >2 ml -rapid reduction concentration of stem cells
- Easy harvest
- Low potency , potency decreases with age
- Commercial growth factors- doubtful efficacy

ALLOGRAFT

- *TYPES (Properties determined by processing)*
- Fresh
 - problems availability, compatibility, storage & disease
- Frozen
 - $<-60^{\circ}\text{C}$
- Freeze dried
 - water removed & vacuum sealed
- Demineralized Bone Matrix (DBM)

ALLOGRAFT

- *ADVANTAGES*

- Unlimited quantity
- Multiple sizes, shapes, forms
- Structural
- Workable
- Osteoconductive
- Osteoinductive?

- *INDICATIONS*

- Large structural defects
- Filler / support
- Autogenous graft expander?
- Cortical/cartilage defects

ALLOGRAFT

Limitations

- Disease transmission (HIV 1:1,000,000)
- Histocompatibility
 - Improved with freezing & processing
- Problems with incorporation
 - Weakens with revascularization
- Reliant on a favorable host bed

Rejection

- Class I & II histocompatibility complex antigens
- Animal studies suggest there is significant response. In humans HLA antibodies are detected but results good.
- Sensitization against other grafts

VertiGraft is a line of allograft bone wedges and shafts designed to provide anterior column support in spinal procedures. Types of bone used include femur, fibula, and humerus. Reprinted, with permission, from DePuy-AcroMed Inc., Raynham, MA.

DEMINERALIZED BONE MATRIX - DBM

- Noncollagenous protein, BMPs, Type-1 collagen
- Acid extraction of allograft bone
- Osteoconduction
- Limited osteoinductive capacity
- Various forms
- Easily stored, readily available

DEMINERALIZED BONE MATRIX

- *INDICATIONS*

- Small stable defects
- Autogenous graft expander
- Allograft enhancer

- *LIMITATIONS*

- Not structural
- Not workable
- Not osteogenic
- Minimal osteoconductive
- Variable osteoinductive capacity

DEMINERALIZED BONE MATRIX

- One Level 1 study in spine showing equivalent rates of fusion using autograft versus autograft and DBM
- Evidence shows differential potencies from lot to lot and manufacturer!
- Considered reprocessed material

BIOSYNTHETIC GRAFTS

- *CERAMICS*
 - Osteoconductive Matrix
 - Composition
 - Hydroxyapatite (HA)
 - Calcium Phosphate
 - Calcium Sulfate
 - Tricalcium phosphate (TCP)
 - Combinations
 - Varying pore size and interconnectivity

Biosynthetic grafts

Pro Osteon is harvested from marine coral exoskeletons that are exothermally converted to hydroxyapatite. The interconnected porous structure closely resembles the porosity of human cancellous or cortical bone. Reprinted, with permission, from Interspace Cross International, Irvine, CA.

BIOSYNTHETIC GRAFTS

Indications

- Small stable defects
- Graft expander or filler
- Use with BMP
- Antibiotic delivery

Advantages

- Availability
- Osteoconductive
- Multiple sizes and shapes
- Structural
- Potentiate BMPs

COMPOSITE GRAFTS

- *Collagen + Ceramic+ Hydroxyapatite*
- Multiple compositions
- Osteoconductive
- Osteoinductive
- Paste or strips
- Malleable

Collagraft strip is comprised of collagen and a composite mineral of hydroxyapatite and tricalcium phosphate.

Reprinted, with permission, from NeuColl Inc., Campbell, CA.

Bone Morphogenetic Proteins - BMPs

- These are included in the TGF- β family
 - Except BMP-1
- BMP2-7,9 are osteoinductive
- BMP2,6, & 9 may be the most potent in osteoblastic differentiation
- Follow a dose/response ratio

BMP – Level-I Evidence

- BMP-2
 - Increased fusion rate in spinal fusion
 - Role for improved wound healing?
 - Role for reducing infection?
- BMP-7 equally effective as iliac crest bone graft in nonunion
- Must be applied locally because of rapid systemic clearance
- Protein therapy vs gene therapy

Technical aspects and complications of bone graft harvest

Choice of bone graft stock

- Depends on location and type of fusion
 - *Cortical bone for mechanical strength and structural support*
 - *Cancellous bone for osteogenic potential*
 - *Cortico-cancellous bone for metal/carbon cages filled with bone chips*

Bone sources autograft / allograft

Cancellous bone

- ❑ All 3 char.
- ❑ Nidus for bone formation
- ❑ Poor wt. bearing
- ❑ Fails under compression
- ❑ Used as –
 - Onlay graft over post elements
 - Packed into facet joints
 - Along with cortical bone or load bearing device in interspace

Cortical bone

- ❑ less osteoinductive and osteogenic
- ❑ Good wt. bearing
- ❑ Resist compression-interbody graft
- ❑ Combination with cancellous augments osteoinductive and osteogenic potential

The iliac crest

Most common source in

neurosurgery

Surgical Anatomy: iliac crest

- Hip Bone:
 - Made of three bones fused in a Y-shaped fashion



Surgical Anatomy: iliac crest

- Bone harvesting:
 - The lateral approach to the anterior ilium affect the gait the most
 - The medial anterior approach involve the large iliacus muscle which is not necessary for normal gait but large medial hematoma might produce gait disturbances

Surgical Anatomy: Iliac crest

- Surgical access:
 - Incision should be placed 1 inch posterior to ASIS and extend to iliac tubercle
 - placed lateral to bony prominence to prevent irritation by tight clothes or belt
 - Proceed down to bone medial to the muscles, tensor fascia lata and gluteus medius and lateral to the iliacus and the external abdominal muscles

Surgical Anatomy: Iliac crest

- Cancellous bone is available in the anterior ilium within the upper 2 – 3 cm and between the tubercle and the anterior superior spine, Iliac crest graft.
- During closure, strict attention to reorient and reposition the muscles in their original positions
- Hemostasis of raw bony surface – gelfoam preferred over bone wax – allows reuse of donor site in future
- A drain is required because of the dead space and should be placed within the bony cavity

Morbidity / complications

- *Acquired* bowel herniation (larger donor sites (>4 cm))-20 cases reported in the literature
- Meralgia paresthetica (injury to the lateral femoral cutaneous nerve also called Bernhardt-Roth's syndrome)
- Pelvic instability
- Fracture (extremely rare)
- Injury to the clunial nerves (this will cause posterior pelvic pain which is worsened by sitting)
- Injury to the ilioinguinal nerve
- Infection
- Minor hematoma (a common occurrence)
- Deep hematoma requiring surgical intervention
- Seroma

- Ureteral injury
- Pseudo aneurysm of iliac artery (rare)
- Tumor transplantation
- Cosmetic defects (chiefly caused by not preserving the superior pelvic brim)
- Chronic pain
- Bone grafts harvested from the posterior iliac crest in general have less morbidity, but depending on the type of surgery, may require a flap while the patient is under GA

The Rib

- Right rib is always preferred because:
- Postoperative pain is less likely to be confused with cardiogenic pain
- **Rib harvesting:**
 - Usually 5th or 6th typical one
 - Incision is placed in the infra-mammary crease, to hide the scar
 - Usually during thoracotomy

- *Success rates with other sources of allograft and autograft struts has made it unnecessary to harvest rib grafts through a separate incision*



- *Convenient during limited thoracic reconstruction because graft can be harvested during thoracotomy*

The tibia

- ***The extensive subcutaneous surface of the tibia makes it an accessible donor site for bone grafts***

Surgical Anatomy: The tibia

- Bone harvesting:
 - The tibial plateau is an excellent reservoir for cancellous bone
 - It can provide up to 40 cc of bone without affecting the structural support of the tibia
-

Surgical Anatomy: The tibia

- Surgical access:
 - Could be done under local anesthesia and conscious sedation
 - Incision over the lateral tubercle best accomplished by flexing the leg at the knee joint
 - It is 6 – 10 mm from the skin and dissection is made through the thin subcutaneous tissue
 - Sharp dissection to reflect the tensor fascia lata band and make 1 cm opening into the cortex and the cancellous bone could be harvested lateral and inferior to the midline to avoid damage to the knee

Fibular autograft

- Used in past as strut graft
- Microvascular anastomosis – vascularized fibular strut graft
- Not gained widespread acceptance-
 - *Success rate of cervical fusion is quite high using nonvascularized fibular auto/allograft with appropriate stabilization*

Thank You