

Bone Cement

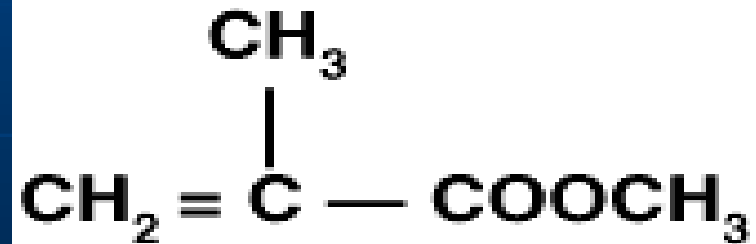
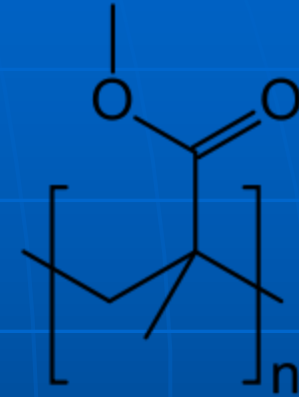
Dr. Jan Cernovsky

Royal National Orthopaedic Hospital Stanmore.



What is bone cement?

- Methyl methacrylate
- Formula: $C_5H_8O_2$
- Molecular Weight 100
- Colourless volatile liquid
- Vapour pressure 29.3 mmHg.

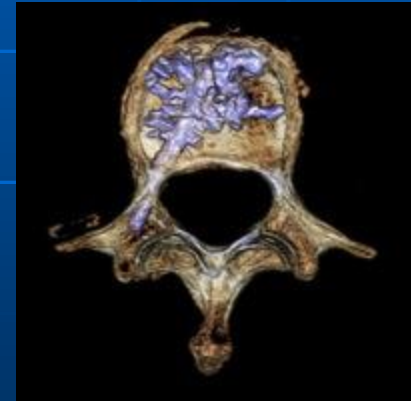
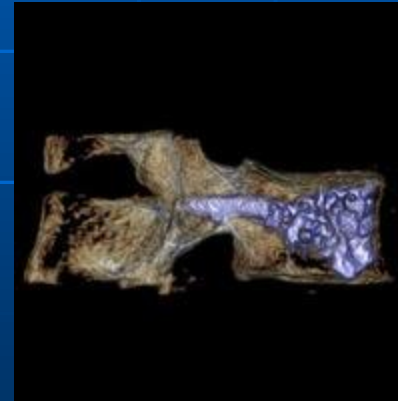
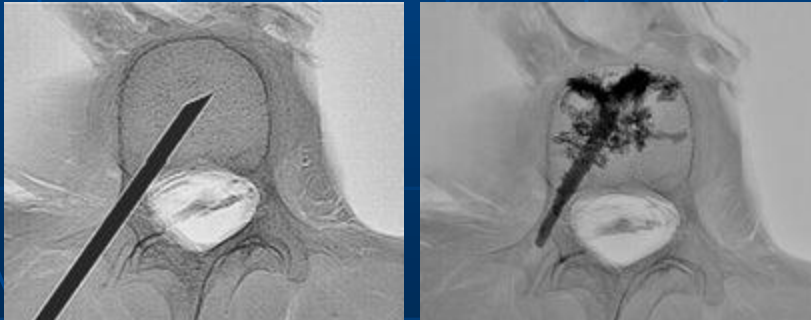


Uses of methylmethacrylate

- Manufacture of resins and plastics
- Cast sheets, advertising signs, lighting fixtures, plumbing and bathroom fixtures
- Impregnation of concrete to make it water repellent

Medical

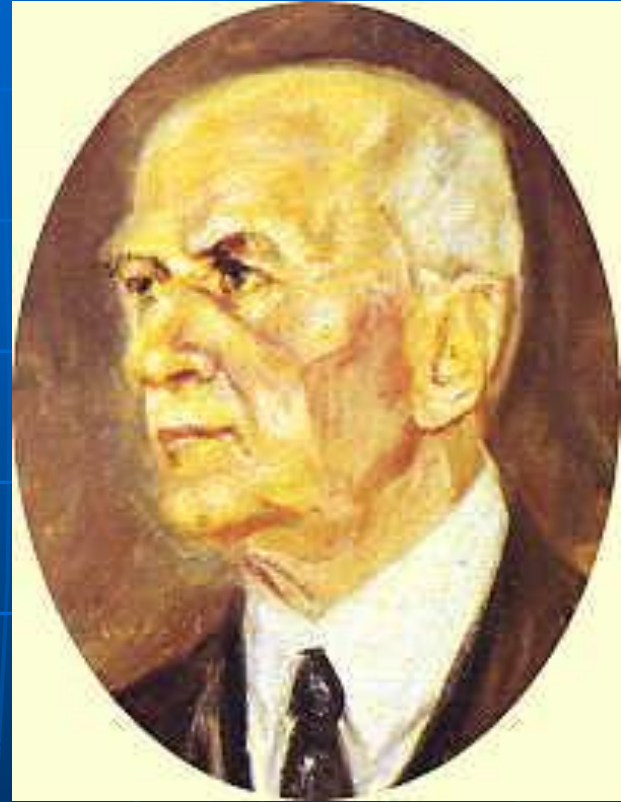
- Joint replacement surgery
 - Total THR+TKR NHS 111,086
 - Total THR+TKR Private 45,718
 - 30% of THRs are uncemented
- Spacers
- Vertebroplasty



History



Otto Rohm



Otto Haas

Medical history



Dr. Haboush USA
Sir John Charnley
In late 1950s.

Preparation of PMMA



- Polymethylmethacrylate
 - Powder polymer
 - Contains initiator - dibenzoylperoxide
 - Liquid monomer
 - Contains activator – N,N-dimethyl-p-toluidine
- Antibiotics
 - Gentamicin, Tobramycin, Clindamycin
- Radiographic contrast
 - Zirconium dioxide or barium sulphate

Ideal Cement

- Easy to prepare, no exothermic reaction
- No fatigue, forever unchanged
- Hard but flexible
- No infection
- No monomer reaction
- No embolic events
- No pro-inflammatory mediators
- No osteolytic reactions

Ideal Cement

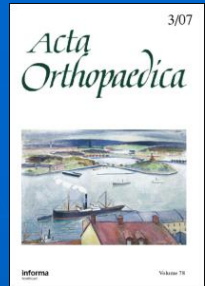
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- No monomer reaction
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Advantages of antibiotic loaded cement

- USA versus Europe– FDA licence
- Most effective prophylaxis for septic complications in arthroplasty
 - Malchau h et al. Prognosis of Total Hip Replacement. American Academy of Orthopaedic Surgeons, Feb 2002, Dallas, USA.
- Reduces the incidence of revision.
 - Havelin L et al. Prospective study of hip prosthesis. Norwegian Arthroplasty register 1987-1999.

Efficacy of antibiotic-impregnated cement in total hip replacement.

Parvizi J et al. *Acta Orthop*.2008 Dec;79(6):870



- 19 studies reporting on 36,033 hip replacements in 35,659 patients met the initial inclusion criteria
- meta-analysis of the published literature
- The rate of deep infection following primary total hip arthroplasty was
1.2% when antibiotic cement was used
2.3% when cement without antibiotics was used (significant)
- For revisions of previously infected hips, combinations or culture-dependent antibiotics lowered infection rates by approximately 40%.

Safety of antibiotics

- Adverse effect on the mechanical strength of methylmethacrylate
- Potential for the emergence of resistant organisms
- **Acute renal failure associated with vancomycin- and tobramycin-laden cement in total hip arthroplasty**

Patrick BN, et al *Ann Pharmacother.* 2006 Nov;40(11):2037-42.

Alternatives to antibiotic loaded cement

- A preliminary study of the release of quaternary ammonium antimicrobial compounds from acrylic bone cement. *J Mater Sci Mater Med.* 2009 Mar 4. prepublished Mathey M et al.
- benzalkonium chloride and cetyl pyridinium chloride

Ideal Cement

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Bone Cement Implantation Syndrome

- NO agreed definition
- hypoxia
- hypotension
- cardiac arrhythmias
- increased pulmonary vascular resistance (PVR)

BCIS-Proposed severity classification

A. J. Donaldson, H. E. Thomson, N. J. Harper and N. W. Kenny, Br J Anaesth
2009; 102: 12–22

- Grade 1: moderate hypoxia ($\text{SpO}_2 < 94\%$) or hypotension [fall in systolic blood pressure (SBP) $> 20\%$].
- Grade 2: severe hypoxia ($\text{SpO}_2 < 88\%$) or hypotension (fall in SBP $> 40\%$) or unexpected loss of consciousness.
- Grade 3: cardiovascular collapse requiring CPR

Intraoperative mortality during total hip replacement

	Coventry <i>et al.</i> (1974)	Ereth <i>et al.</i> (1992)	Parvizi <i>et al.</i> (1999)
Uncemented THR		0%	0%
Cemented THR	0.06%	0.12%	0.09%
Cemented THR (no fracture)			0.06%
Cemented THR (non-pathological fracture)			0.14%
Cemented THR (pathological fracture)			0.68%

WHY?

- **Monomer model**
- **Embolic model**
- **Mediator effect**

Monomer model

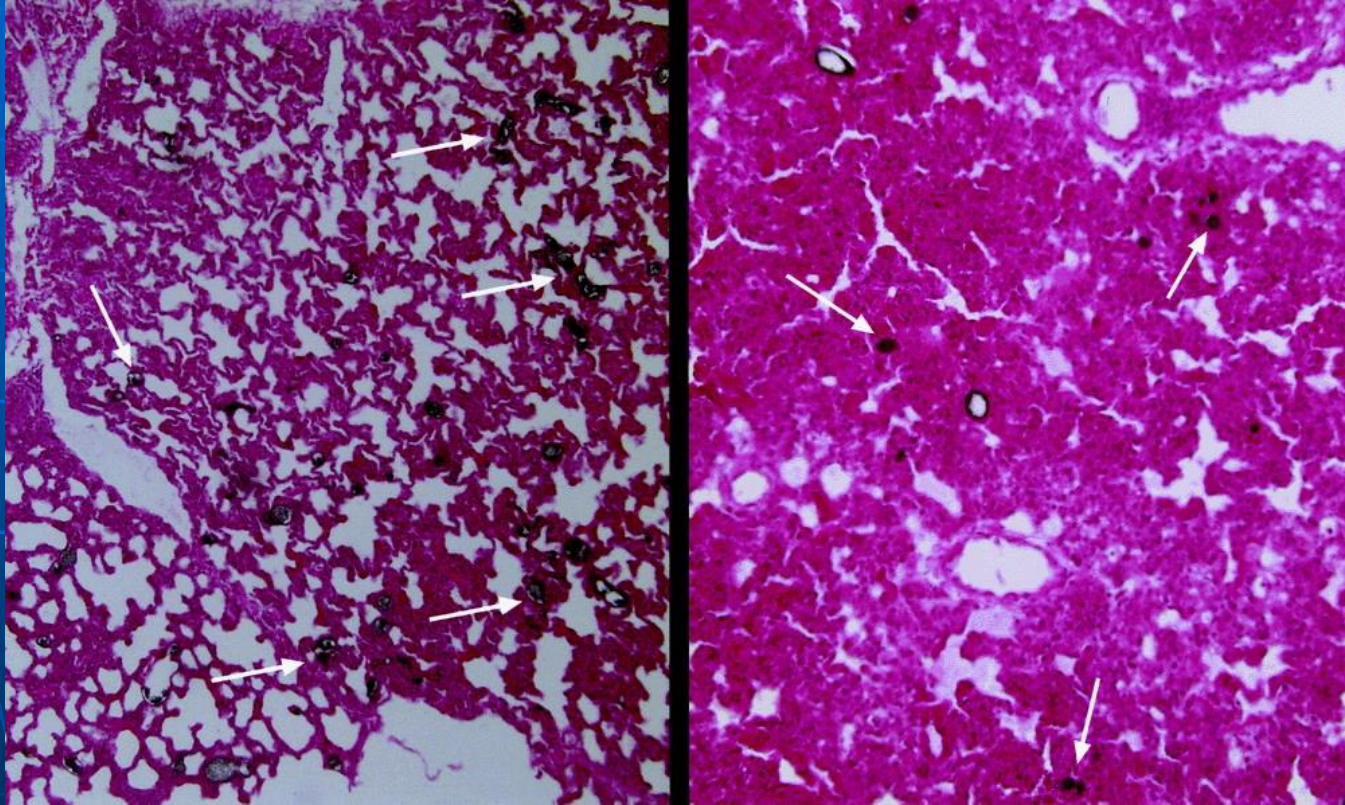
- **Myocardial depression:** concentration dependent→ depress Ca influx through cardiac membrane
Direct myocardial depressant effect of methylmethacrylate monomer
Anesthesiology 2003; 98(5):1186-94
- **In vitro monomer causing hypotension**
- **!!!!!!!plasma MMA concentration after cemented hip arthroplasty is considerably lower than the concentration required to cause pulmonary or cardiovascular effects!!!!!!!!!!!!**

Embolic model

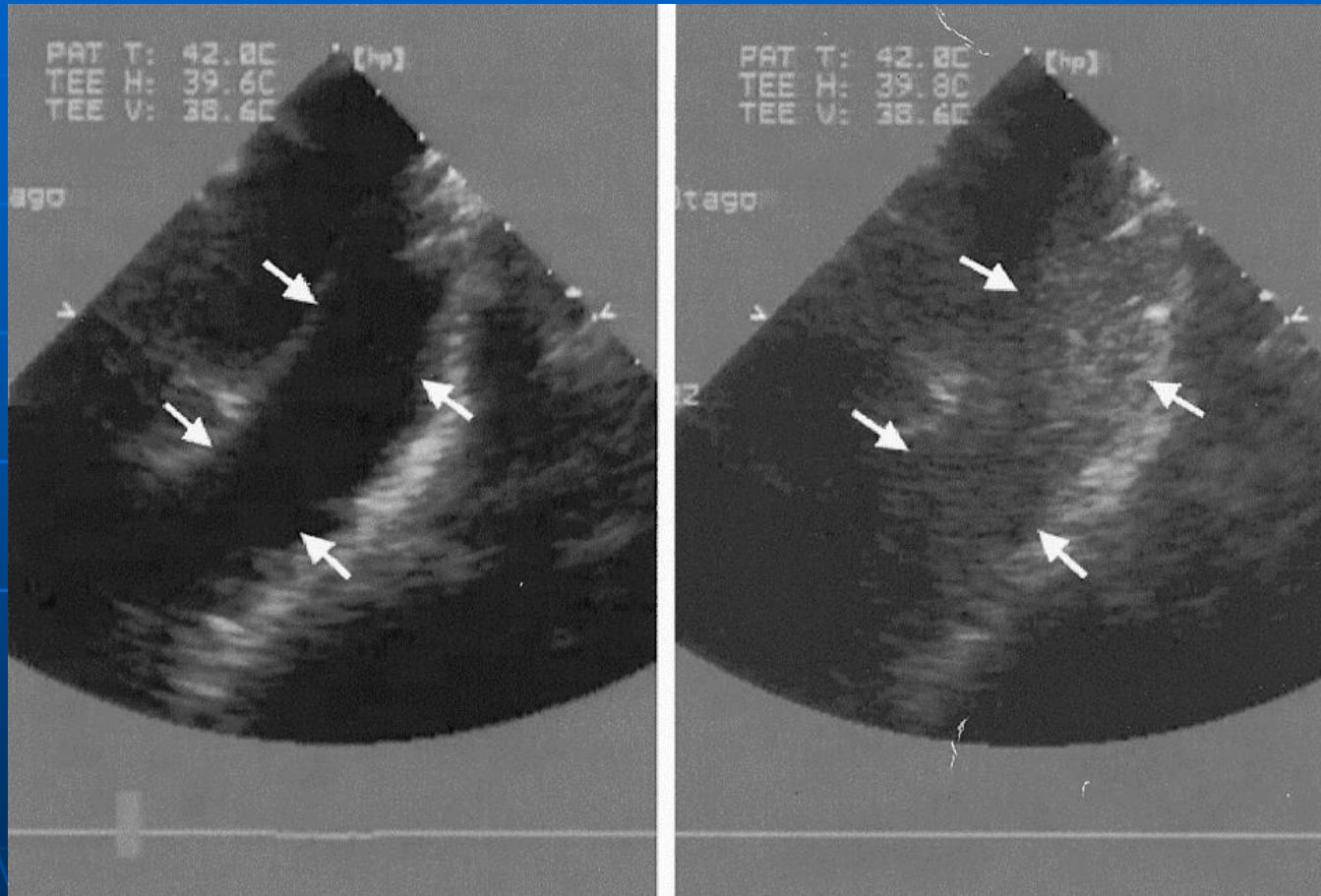
- **Mechanical effect** debris includes marrow, fat, cement particles, air, bone particles, and aggregates of platelets and fibrin.
- High intramedullary pressure is the main causative factor for fatty marrow release into the circulation causing pulmonary fat embolism in all patients during intramedullary nailing and hip and knee replacements.

Hofmann, S.; Huemer, G.; Salzer, M. **Pathophysiology and management of the fat embolism syndrome.** Anaesthesia Vol 53 May 1998.

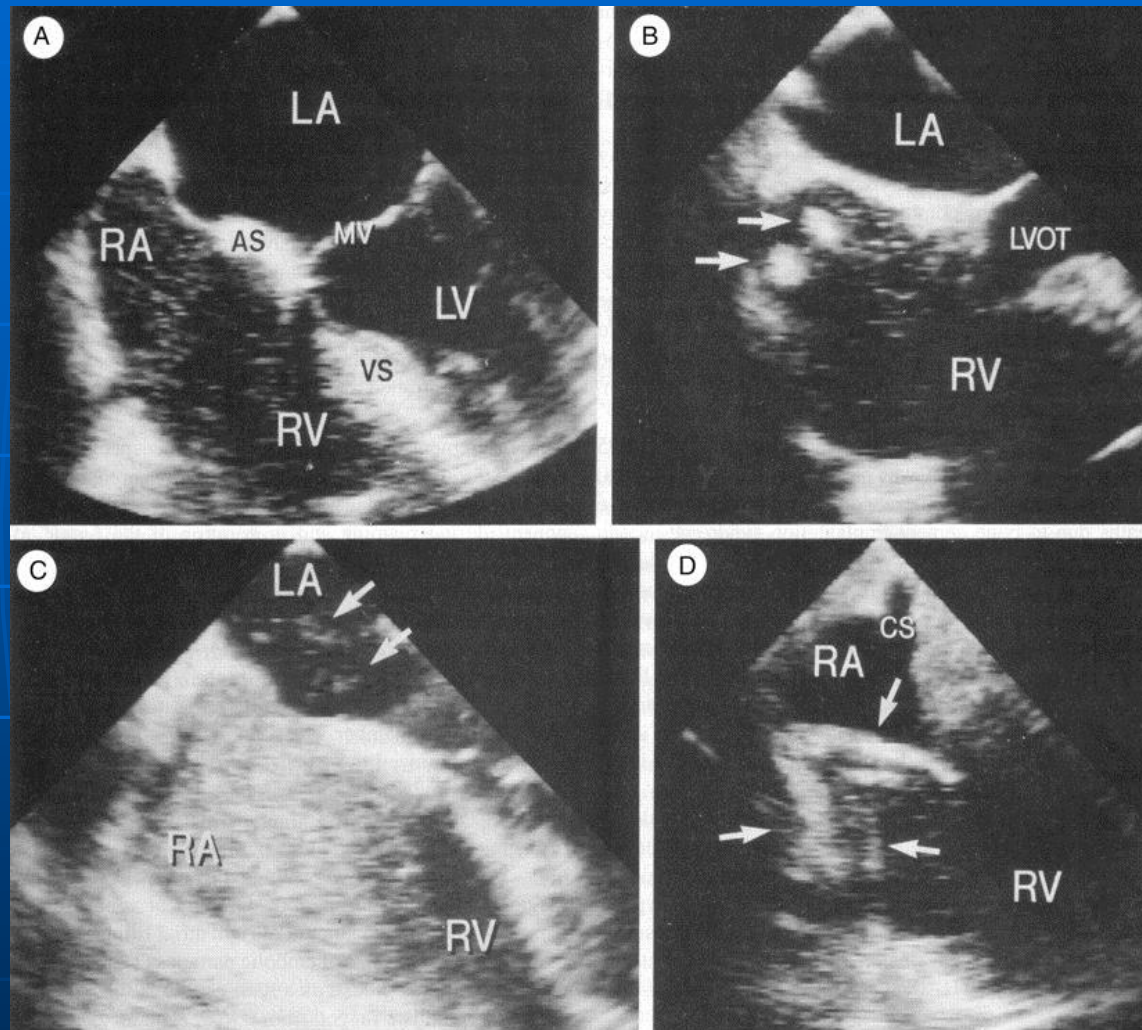
Fat in lungs



Snow storm in pulmonary artery



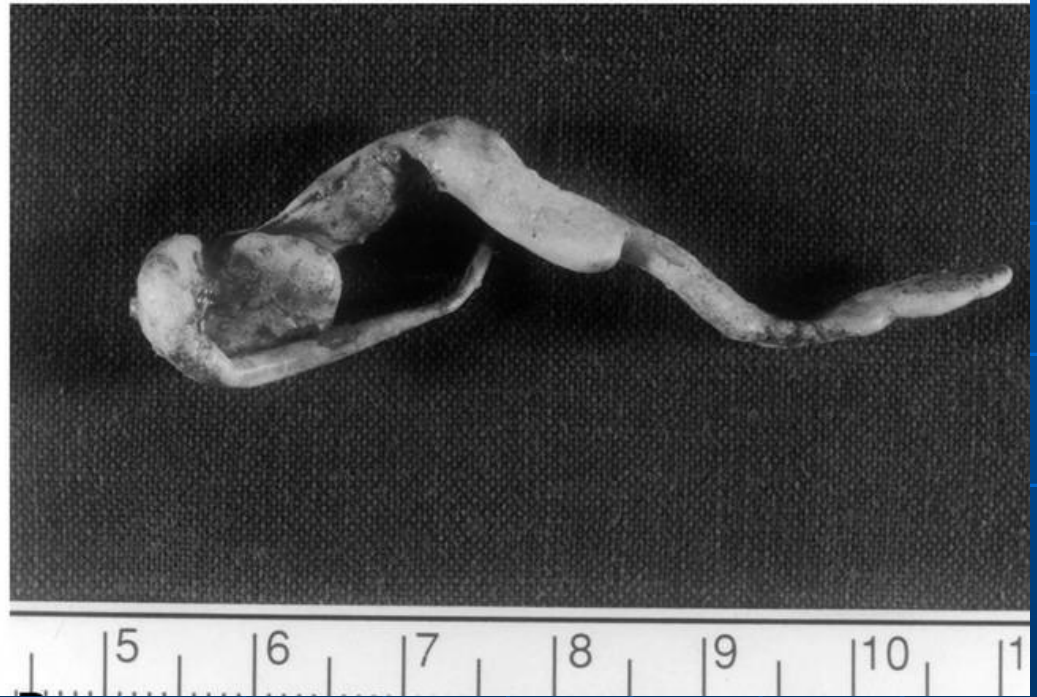
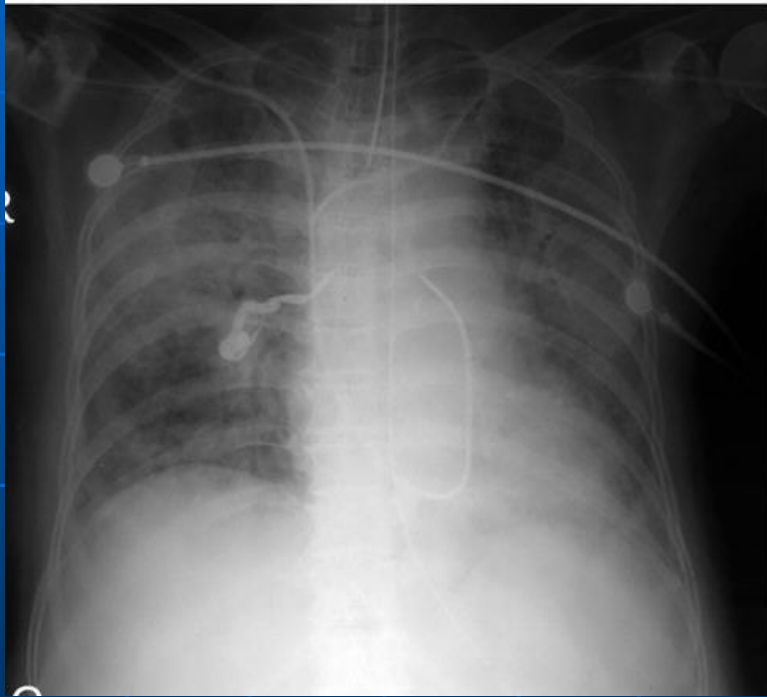
Four chamber TOE views showing embolism during total hip arthroplasty.



Cement in pulmonary artery



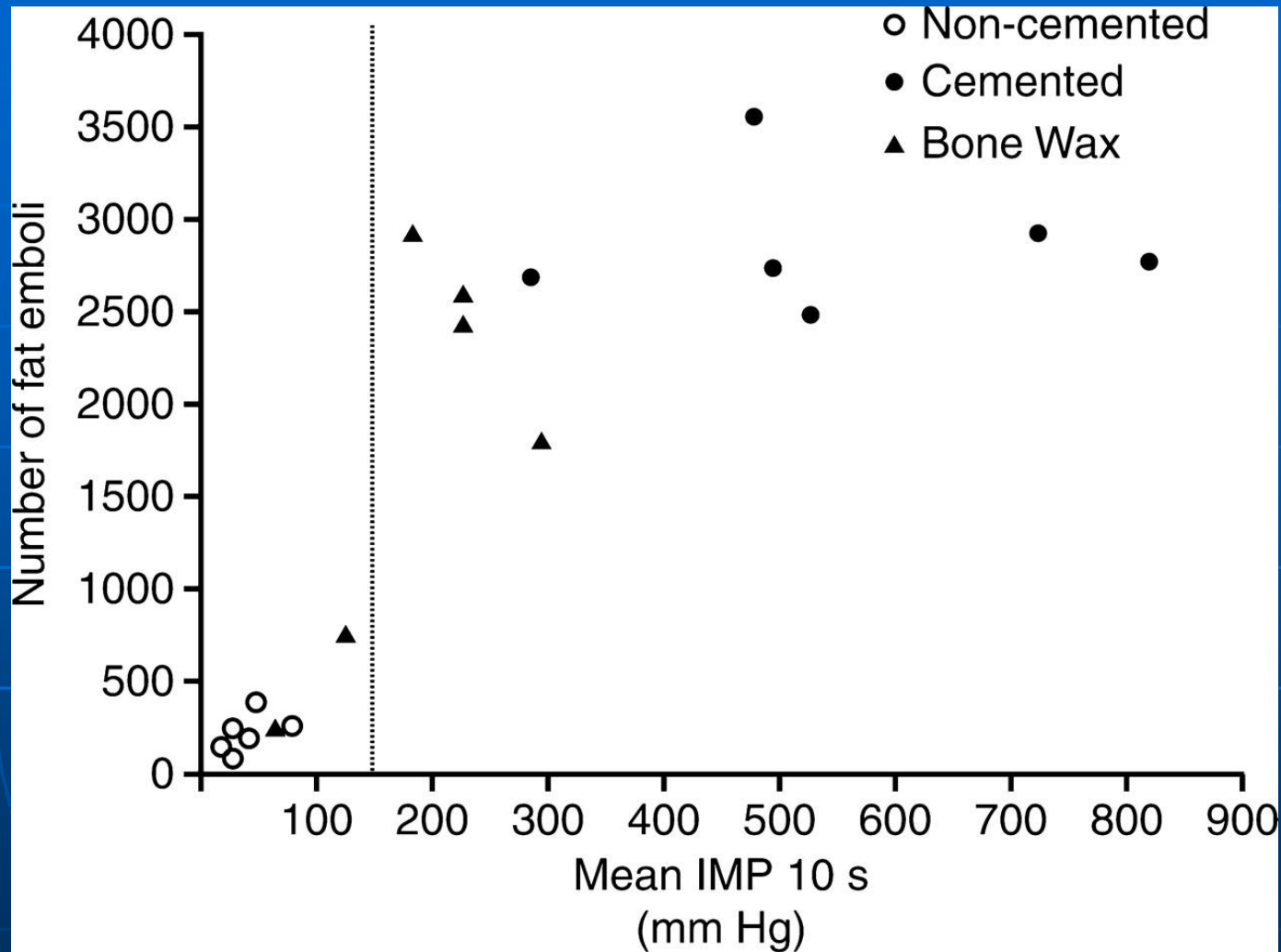
Cement embolectomy



The Clinical Relevance of Embolic Events Detected by Transesophageal Echocardiography During Cemented Total Hip Arthroplasty: A Randomized Clinical Trial

- **Matthias J. Koessler, MD*, Renato Fabiani, MD*, Hendrik Hamer, MD, and Rocco P. Pitto, MD, PhD**
- **Anesth Analg 2001;92:49-55**
- **120 patients**
- **Conventional versus Modified technique**
- **grade 2 embolic event were imaged during the insertion of the stem in**
 - 93.4% patients by using conventional cementing technique
 - 13.4 % patients by using the modified technique

Number of fat emboli in the lungs (area of 1200 mm²) and the maximum mean intramedullary pressure (IMP) over a 10-s interval.



Orsini EC, Byrick RJ,

. Cardiopulmonary function and pulmonary microemboli during arthroplasty using cemented or non-cemented components the role of intramedullary pressure. *J Bone Joint Surg* 1987;69:822-32

Embolic mediated model -
???**Mechanical effect**???

degree of cardiovascular
compromise is not
necessarily proportional to
the degree of the embolic
load

Embololic model –

Mediator effect

- Damaged endothelium, reflex vasoconstriction or release of endothelial mediators.
- Histamine release
- Release of anaphylatoxins C3a & C5a
- release vasoactive or pro-inflammatory substances that directly increase PVR- thrombin and tissue thromboplastin, platelet derived growth factor (PDGF), serotonin (5-HT), thromboxane, platelet activating factor
- Release of endogenous vasodilators

Endogenous cannabinoids!

Takashi M, Teruto H, Tomonori, Munekazu Y,
Noboru T, Setsuro, Ikuro M.

Endogenous Cannabinoids are Candidates for Lipid Mediators of Bone Cement Implantation Syndrome

anandamide (ANA)

2-arachidonylglycerol (2-AG),

- Shock. 21(1):8-12, January 2004.

Serum Astroglial S-100B protein

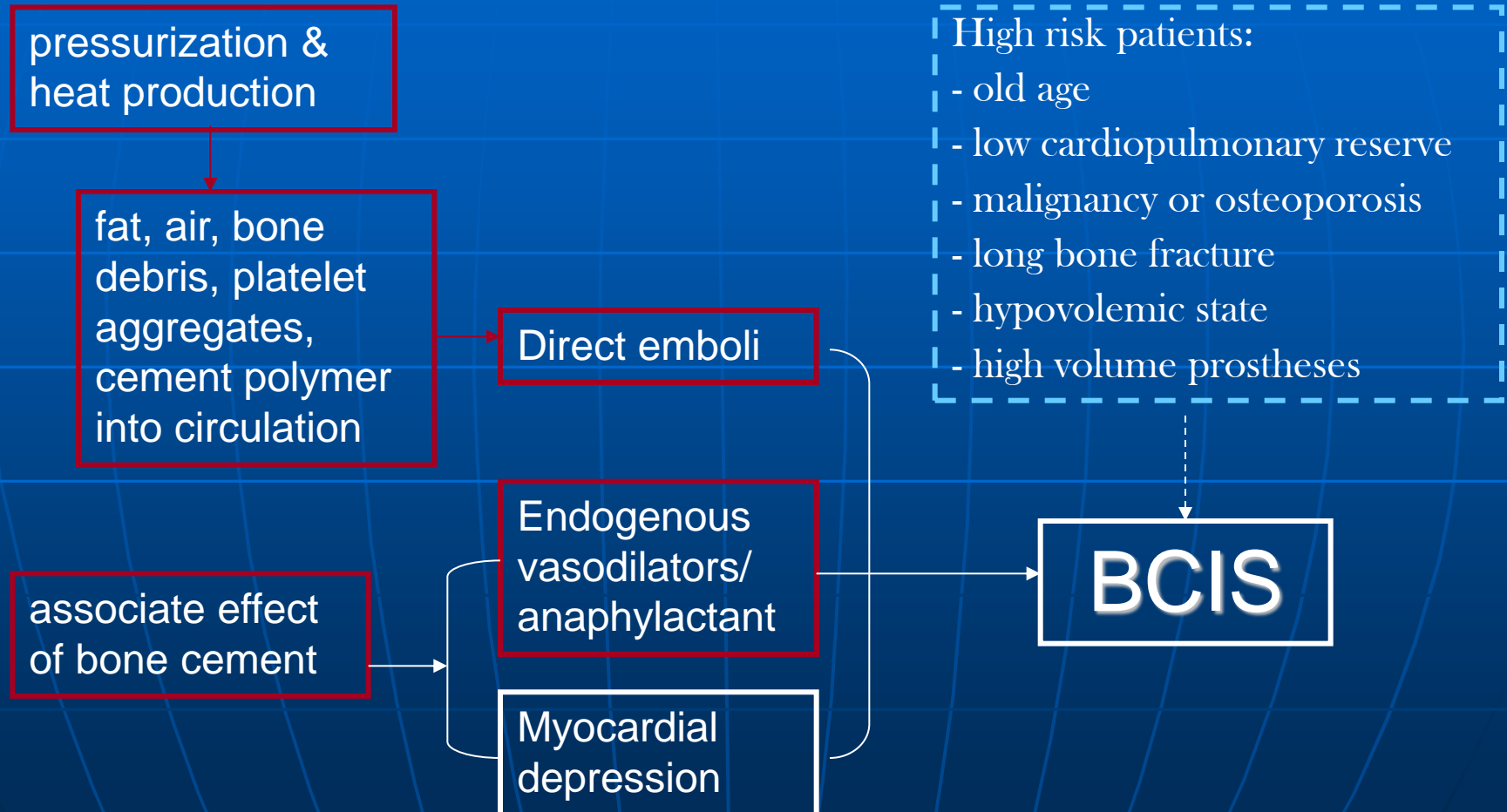
- Released from damaged schwann & glial cells
- Sensitive marker of cerebral damage
 - Shaaban A, Harmer M, Vaughan R. Serum S100 protein as a marker of cerebral damage during cardiac surgery. BJA 2000;85:287-98
- Serum conc. after stroke and head injury are prognostic.
 - Raabe A, Grolms C, Seifert V. Serum markers of brain damage and outcome prediction in patients after severe head injury, BJ of neurosurg 1999;13:56-9

Kinoshita H, Iranami H, Hatano Y et al.

The use of bone cement induces an increase in serum astroglial S-100B protein in patients undergoing total knee arthroplasty.

Anaesth Analg 2003;97:1657-60

Proposed mechanism of BCIS



RISK FACTORS for BCIS

- Surgical factors
 - Pathological fracture
 - Inter-trochanteric fracture
 - Long-stem arthroplasty



Management

- Investigation of co-morbidity + pre-optimization
 - ASA III-IV
 - Pre-existing pulmonary hypertension
 - Significant cardiac disease
 - Poor pre-existing physical reserve
 - Osteoporosis
 - Old age
 - Hypovolaemic state

Management

- Prevention
 - Methylprednisolone
- W. Gammer Inhibition of Complement Activation by High-dose Corticosteroids in THA, *Clin Orthop relat res* 1998;236:205-9
 - Antihistamines H1 H2
- Lamade WR ;Bone cement implantation syndrome. A prospective randomised trial for use of antihistamine blockade. *Arch Orthop Trauma Surg*; 1995;114(6):335-9 Heidelberg, Germany
- Tryba M; Histamine release and cardiovascular reactions to implantation of bone cement during total hip replacement. *Anaesthetist* ; 1991 Jan;40(1):25-32

Management

- Investigation of co-morbidity + pre-optimization
- Prevention
 - Methylprednisolone
 - Antihistamines H1 H2
- Be aware and vigilant
- Know the procedure and surgeon
- Invasive monitoring
- Haemodynamic support
- O2
- fluids
- CPR

Management

■ Surgical

- Aggressive medullary pulse lavage
 - good haemostasis
 - minimising the length of prosthesis
 - venting the medulla
 - canal suctioning during cementation
 - placement of a venting hole
 - avoid excessive cement pressurization
 - slow, controlled insertion of the prosthesis
-
- Fat embolization and fatal cardiac arrest during hip arthroplasty with methylmethacrylate. Canadian Journal of Anesthesia. 2001 Jun; 48:626-9

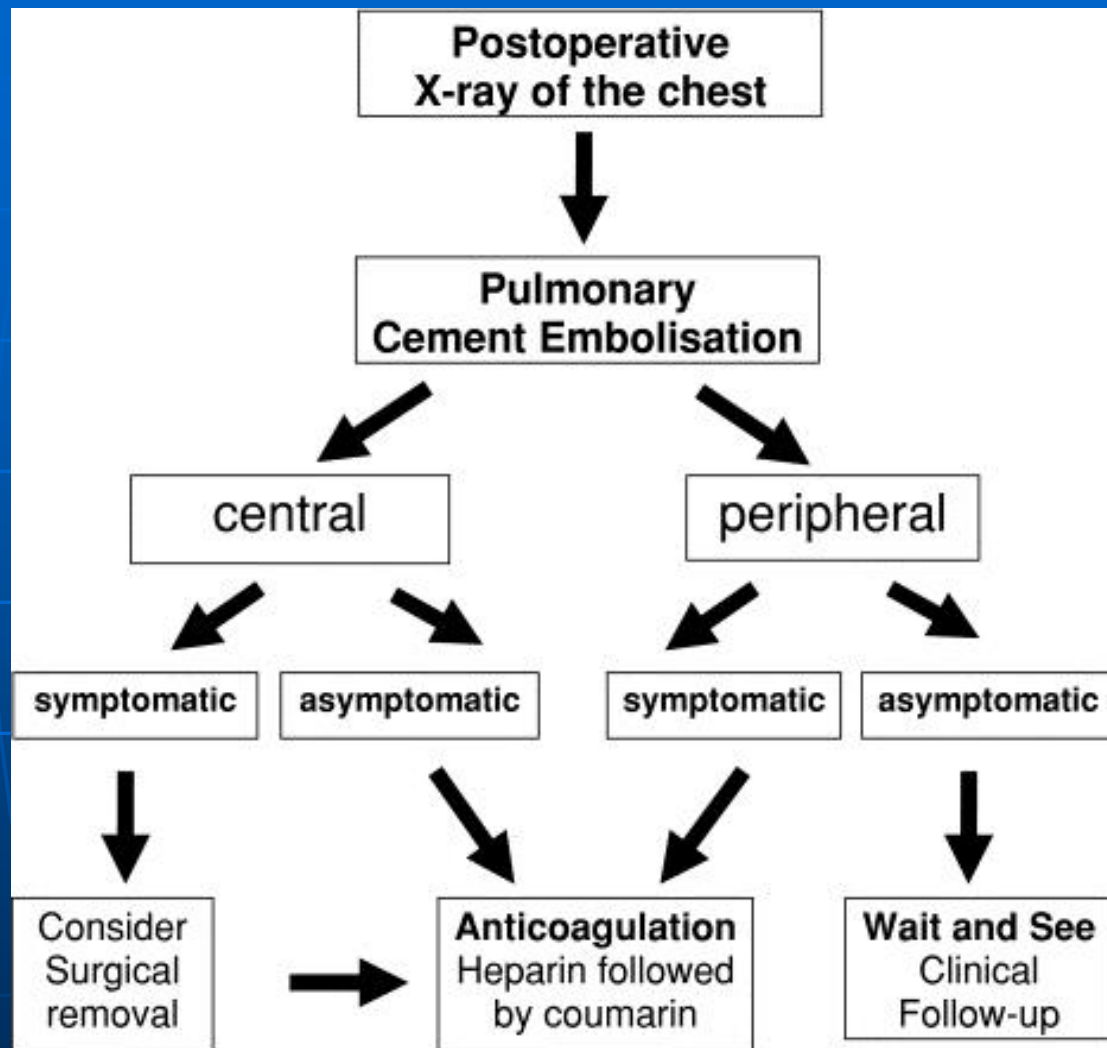
Guidelines for antibiotic prophylaxis and treatment for high risk patients with haematological malignancies undergoing orthopaedic procedures

Guidelines for antibiotic prophylaxis and treatment for high risk patients with haematological malignancies undergoing orthopaedic procedures

- Mandatory : FBC, U&E, LFTs, Clotting, MRSA screen
- START of antibiotic treatment prior to the procedure
- Myeloma patients often GFR less than 40 ml/min =need for reduction of the dose
- Antibiotic treatment for 7 days
- Avoid NSAID's
- Stop anticoagulation prior the procedure

Guidelines for antibiotic prophylaxis and treatment for high risk patients with haematological malignancies undergoing orthopaedic procedures

- Oral ATB on days : -1 from the procedure to day 7
 - Augmentine 625 mg TDS
 - Ciprofloxacin 500 mg BD
- IV ATB on days : -1 from the procedure to day 7
 - Tazocin 4.5 g IV TDS
 - Teicoplanin 400 mg IV q12 hours for 3 doses then 400 mg OD



Limitations of PMMA

- Precision during preparation, air bubbles, monomer vapour, vacuum
- Poor adhesion of the bone cement to the bone surface
- High exothermic reaction during polymerization (still low for perfect results)
- Toxic complication
- BCIS
- Mechanically weak because it has entrapped impurities such as air and blood,
- Brittle, it has low endurance limit and is prone to fatigue failure.
- Hard crystals of Barium sulfate do scratch and damage the fine joint surfaces of the artificial joint.
- Small cement particles may cause osteolysis - "bone dissolving disease"
- Very large surface which support colonization of bacteria and development of postoperative infections

Bone substitutes in vertebroplasty

Heini PF, Berlemann U. *Eur Spine J*. 2001 Oct;10 Suppl 2:S205-13

- Composite cements : acrylic cements in conjunction with ceramics
- Bioactive
- highly radiopaque
- feature excellent mechanical properties
- "Cortoss"

Development and clinical application of artificial bone and bioactive bone cement in Japan

- Yamamuro, T. *Biomedical Engineering Conference, 1995., Proceedings of the 1995 Fourteenth Southern Volume* , Issue , 7-9 Apr 1995 Page(s):129
- Apatite- and wollastonite-containing glass-ceramic (AG-GC)
- has excellent biocompatibility
- used in 4,113 clinical cases



N-acetyl cysteine (NAC)-mediated detoxification and functionalization of poly(methyl methacrylate) bone cement.

Tsukimura N et al *Biomaterials*. 2009 Mar 18

- NAC incorporation restored to the normal level compromised bone viability
- NAC incorporation restored suppressed osteoblasts on untreated bone cement.
- Spike of free radical generation ended within 12h
- control bone cement, peak level lasted for 6 days and a level greater than half the level of the peak was sustained for 20 days.
- NAC increased level of antioxidant glutathione in osteoblasts.

Development and clinical trial of a novel bioactive bone cement

John CY LEONG *Front. Med. China* 2008, 2(2): 117–126

- Strontium (Sr)
- superior to conventional PMMA bone cement in :
 - bioactivity
 - biocompatibility
 - osseointegration.
- Mechanically strong,
 - for percutaneous vertebroplasty total hip replacement

Thank you.